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Advanced Space System Concepts and Their Orbital Support Needs (1980-2000)

Volume IV: Detailed Data - Part II: Program Plans and Common Support Needs

(A Study of the Commonality of Space Vehicle Applications to Future National Needs)

(UNCLASSIFIED VERSION)

Prepared by

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Advanced Mission Analysis Directorate
Advanced Orbital Systems Division

April 1976

Prepared for
OFFICE OF SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C.

Contract No. NASW 2727

Systems Engineering Operations

THE AEROSPACE CORPORATION

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VOLUME IV: Detailed Data - Part II: Program Plans and Common Support Needs

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FOREWORD

This report documents the results of Study 2.5, "Study of the Commonality of Space Vehicle Applications to Future National Needs," performed under NASA contract NASW 2727, during Fiscal Years 1975 and 1976. Capt. R. F. Freitag and Mr. F. S. Roberts, Advanced Programs, Office of Space Flight, NASA Headquarters, provided technical direction during the course of the effort. The report is being issued in separate classified and unclassified versions.

This report is comprised of four separate volumes entitled:

Volume I	Executive Summary
Volume II	Final Report
Volume III	Detailed Data - Part I: Catalog of Initiatives, Functional Options; and Future Environments and Goals
Volume IV	Detailed Data - Part II: Program Plans and Common Support Needs

The first two volumes summarize the overall report. The third volume presents a catalog of the initiatives and functional system options; and thoughts on future environments and needs. The fourth volume matches the "initiatives" against the requirements and presents detailed data on alternate program plans for alternate future scenarios, from which likely supporting vehicle and technology needs are derived.

This volume contains a detail treatment of the methodology used for program plan generation, including the alternate world scenarios which were postulated; the plan

construction directives which resulted from consideration of the scenarios; the program plans themselves; the needs for support transportation and orbital facilities implicit in the program plans; and an extraction of those support needs likely to be needed in common between NASA and the DoD in the 1980-2000 time period.

ACKNOWLEDGMENTS

The study was performed for NASA under the direction of Mr. I. Bekey, Study Director and Assistant Group Director of the Advanced Mission Analysis Directorate.

The bulk of the innovative technological material was prepared by I. Bekey and Dr. H. Mayer jointly in a collaborative team effort. The material dealing with the future environments and goals was prepared primarily by Dr. H. Mayer. The programmatic material was prepared by Dr. M. Wolfe and I. Bekey jointly. The marshalling of other Aerospace Corporation resources including system weights estimation was performed by Dr. M. Wolfe. Cost estimation was aided by Mr. H. Campbell. The program evaluation algorithm and the extent of the spectrum of alternate world scenarios were provided by Dr. G. V. Nolde, consultant. Mrs. Janet Antrim provided invaluable and patient support in copy preparation and manuscript typing. The dedicated efforts of all participants are hereby gratefully acknowledged.

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SECTION 1

INTRODUCTION

INTRODUCTION

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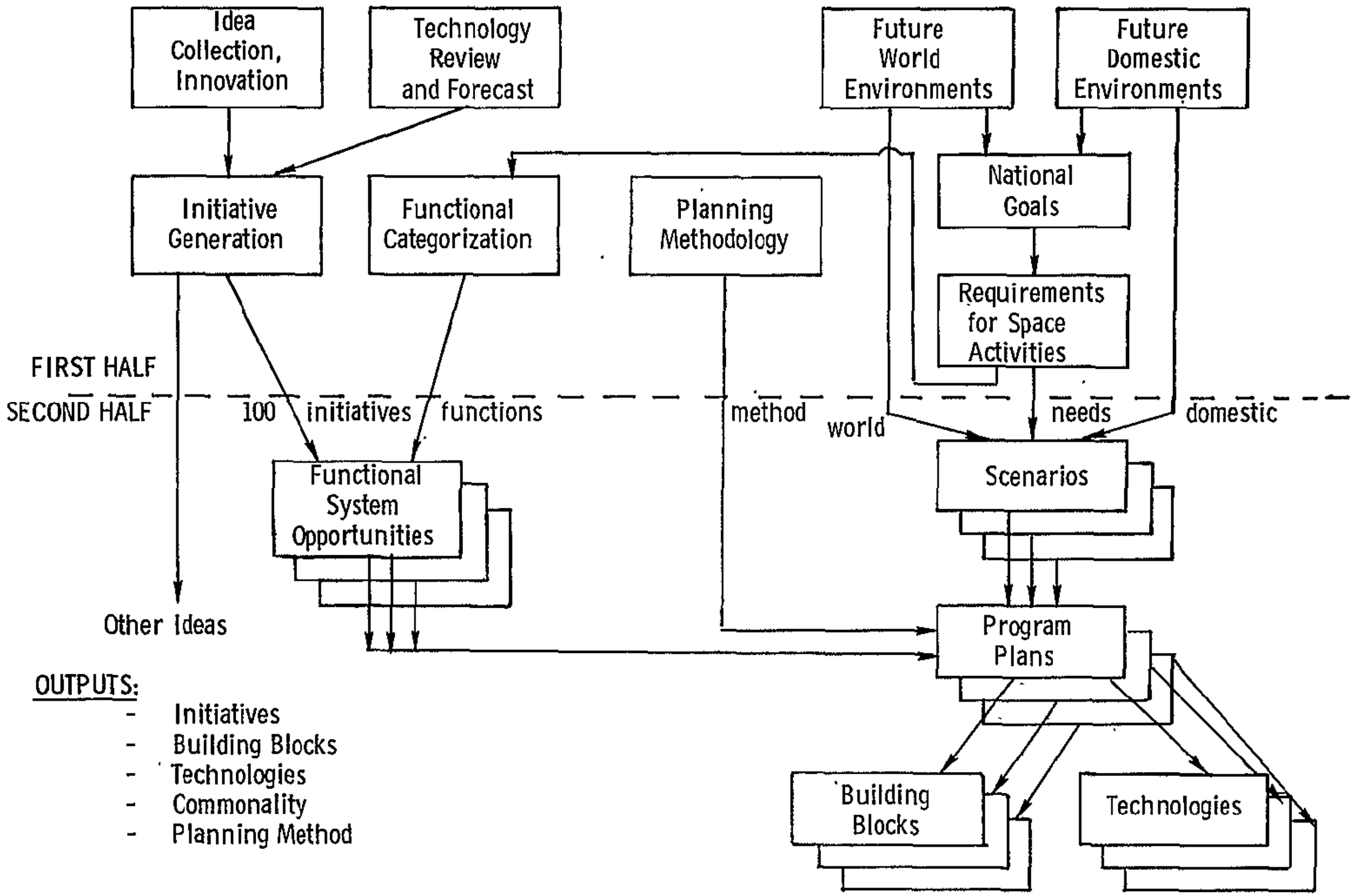
This volume of the final report on the Study of the Commonality of Space Vehicle Applications to Future National Needs contains that part of the study dealing with the derivation of program plans utilizing the initiatives, functions, and domestic and world environments which were generated in the first half of the study and are reported in Volume III; and analysis of the program plans to extract required building block and technology supporting needs, from which common NASA and DoD needs in the 1980-2000 time period are derived.

The methodology of alternate world future scenarios is utilized for selecting a plausible, though not advocated, set of future scenarios each of which results in a program plan appropriate for the respective environment. Each such program plan gives rise to different building block and technology requirements, which are analyzed for common need between the NASA and the DoD for each of the alternate world scenarios. An essentially invariant set of system, building block, and technology development plans is presented at the conclusion, intended to allow protection of most of the options for system concepts regardless of what the actual future world environment turns out to be. Thus, building block and technology needs are derived which support 1) each specific world scenario; 2) all the world scenarios identified in this study; or 3) generalized scenarios applicable to almost any future environment.

The output of the study included in this volume consists of the "building blocks," i.e.: transportation vehicles, orbital support vehicles, and orbital support facilities; the technology required to support the program plans; identification of their features which could support the DoD and NASA in common; and a complete discussion of the planning methodology.

OUTLINE OF STUDY



OUTPUTS:

- Initiatives
- Building Blocks
- Technologies
- Commonality
- Planning Method

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SECTION 2

METHODOLOGY

METHODOLOGY

A number of techniques are known for constructing program plans in such a form as to allow ready extraction of building block and technology needs. Since the method used for construction of the program plans from which the commonality conclusions are derived can greatly influence the results obtained, it was initially intended that several techniques would be utilized in parallel, with the inclusion or exclusion of particular system initiatives from any particular program plan being decided on the basis of selection criteria which are: (1) wholly numerical, (2) wholly subjective, and (3) combination schemes which utilize numerical evaluation factors as an aid in the judgment process. It was decided part way through the study due to the unexpected emphasis on the initiative system concepts of Volume III, that time and resources did not permit the application of more than one such methodology in the desired depth; consequently the method of alternate world scenarios was selected as one which could utilize the future world environment data (generated in the first part of the study and appearing in Volume III) effectively, and yet be capable of yielding program planning data not tied to any one particular interpretation of what the future will be like. The intent was to generate a set of program plans responsive to a set of alternate scenarios which are so defined as to represent a reasonable spectrum of possible futures, so that most futures which reasonable people might conceive would fall inside the spectrum covered. Past studies have shown that useful results can be obtained using such techniques without embracing any particular version of the future, which might otherwise prove controversial, differ from listener to listener, and detract from the utility of the work.

A very limited separate methodology activity was undertaken in parallel with that of the alternate world scenarios with an aim to provide a quantitative algorithm which could be used for the objective cost/benefit evaluation of program plan material, once the required variables and their value have been identified. A first cut at such an algorithm has been derived and is presented in Appendix A of this volume. Perusal of this Appendix will quickly indicate that a large number of variables must be quantified in terms of the system's utility under the particular future world conditions being considered. Once this is accomplished, whether done subjectively, by consensus, or by fiat, program plans can be evaluated quantitatively and rank ordered. Much more work is recommended on such algorithms should there be serious interest in their use.

For all of the above reasons, it is the method of alternate future scenarios which has been selected for use in this study as a tool for developing alternate program plans, in order to derive common NASA/DoD supporting needs.

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SECTION 3

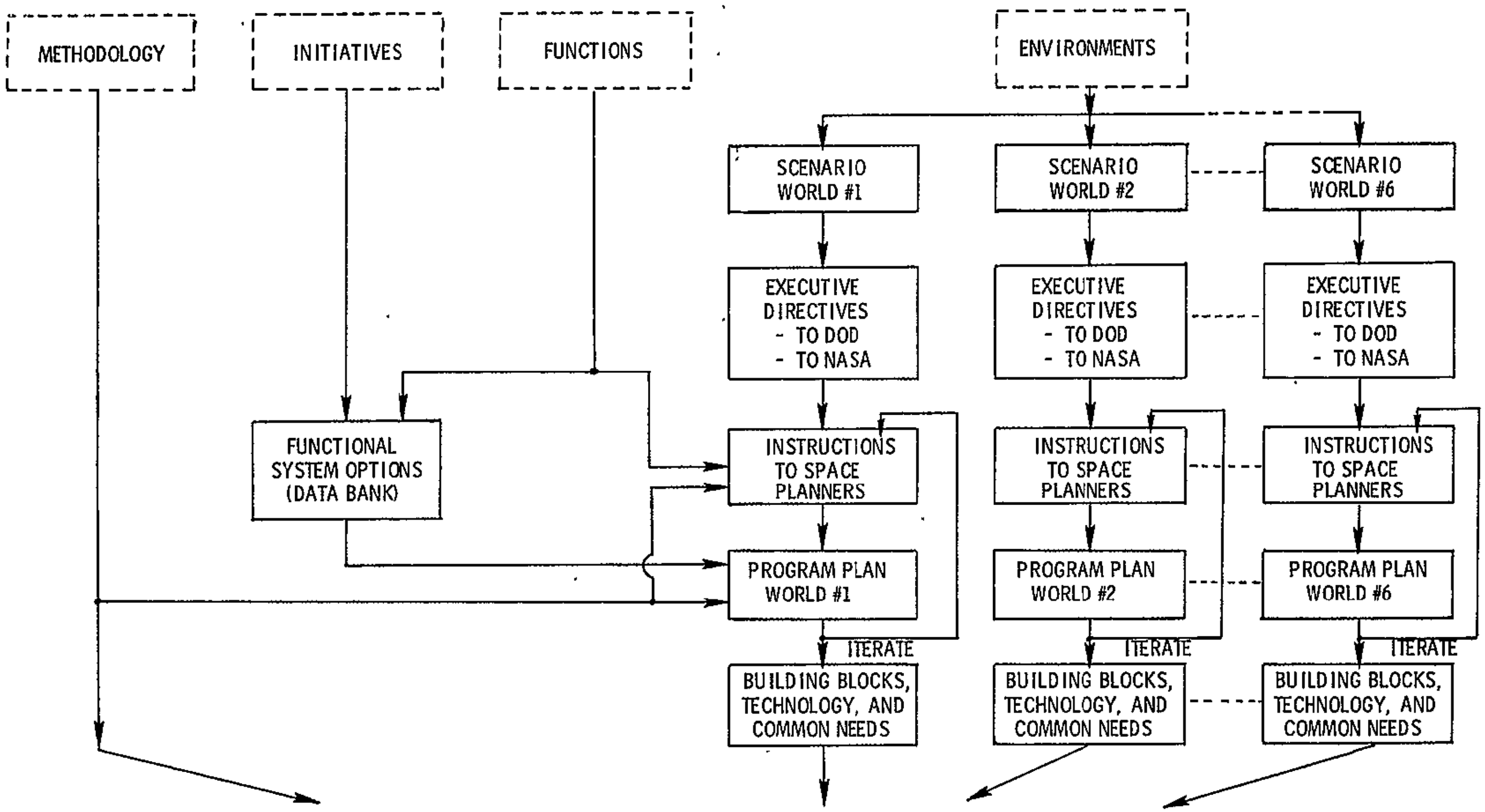
ALTERNATE WORLD SCENARIOS

The outline of the program planning portion of the study is shown in the diagram on the facing page. The outputs of the previous portions of the study are utilized in generation of the alternate world scenarios. For each scenario a set of executive directives is derived, intended for guidance to the NASA and DoD for structuring their programs consistent with the kind of scenario and the latent information in its definition. These executive directives are then amplified for each scenario resulting in specific instructions for the construction of program plans responsive to the scenarios, formatted using the functional system categorization scheme evolved in the first half of the study. Thus for each space function, instructions are developed to enable six alternate program plans to be generated.

The program plans are thus developed utilizing the specific instructions derived above to select initiatives from the functional system options data bank, which contains the initiatives collected and conceived during the first half as well as initiatives based on the NASA and DoD mission models. These program plans are developed as a function of time, and their yearly cost is estimated. The sum of the cost of the program plans is then compared with the budget contained in the executive directives for the particular world being considered. If the program plan is grossly different than the budget requirements in the particular world, the program plan generation method is iterated until a rough correspondence is obtained.

Once the six alternate program plans are thus generated, supporting "building block" transportation vehicles, orbital support facilities, and needed technologies are extracted for each program plan. It is this information which is utilized for assembling the output of the study, i.e., the separate and common NASA/DoD needs for building blocks and technology for each particular world considered, as well as general development plans for systems, building blocks, and technologies which protect most of the options and are not dependent on particular assumptions of the future.

Outline of Program Planning Portion of Study



OUTPUTS:
- MISSION OPPORTUNITIES; COMMON AND SEPARATE
- COMMON NEEDS FOR DOD AND NASA
- TECHNOLOGY DEVELOPMENT PLANS
- BUILDING BLOCK DEVELOPMENT PLANS
- PLANNING METHODOLOGY

In order for a methodology based on future world scenarios to be useful, it must be based on views of the future encompassing a large spectrum of possibilities, both domestic and international, which include most of the reasonable options which significant numbers of authorities would be likely to include if they were questioned. That is a very great order indeed, and clearly can only be approached, particularly in a very limited study such as this. Consequently the scenarios were constructed from two main sources of information. The first contained the views of the future developed in the first portion of the study from discussion with selected, informed, and authoritative people including members of the scientific community, government, industry (a list of people contacted for discussions is contained in Volume III); a review of documentation published in long-term projections or long-term views of the world in the next century or toward the end of the century; and in-house thoughts in this area. The draft resulting from that effort was checked against the second source: the "Outlook for Space" study portion on future world environments. The Outlook for Space study made a very comprehensive and thorough investigation in this direction, possibly the best that has yet been done. Some of the pertinent material that was developed by the responsible working group as well as some raw tapes from the Smithsonian Institution Symposium on Future Environments were reviewed as a second major source of inputs for our study. It was heartening to note that generally there was very little discrepancy between the gross notions of the future developed in the first part of our study and those which were generated by the Outlook for Space future environment investigation. Our study, of necessity, was broader than that of the Outlook for Space since it had to include the international ideological and military environment in considerable depth. On the other hand, our study was not able to be as deep, as thorough, and as detailed in the world situations in general and in the domestic situations in particular, in which the Outlook for Space study material is outstanding.

The combination of data sources discussed above gave us a feeling that while we could not, of course, predict the future, we had a reasonable feel for the likely trends in areas crucial to program planning; and while we make no claim for the uniqueness of the conclusions, we are reasonably confident that we haven't erred in a gross way. It is unlikely that conclusions from any of the more recognized sources would be grossly different in particulars that radically impact the support needs of space systems.

The problem then narrowed to the spectrum of conditions that should be reflected in the world scenarios, i.e., should the scenarios treat only variants of highly likely alternate scenarios, lending relatively little insight on the impact of the entire broad spectrum of futures including extreme or catastrophic views of what the future might hold; or should the scenarios cover the broad spectrum of futures at the expense of many of the more moderate and perhaps more likely views of the future. After some thought it was decided that the latter view would best serve a very limited study such as this one because it would lend insight to supporting needs and common functions for other conditions, even those that were not likely; it being then possible to make some generalized statements on common supporting needs not tied to any particular view of the future and thus applicable to any view. It must be emphasized at this point that none of the scenarios which were selected is advocated by The Aerospace Corporation or by the study team in any way. They are simply an attempt to place bounds on the future conditions to be represented in this study and from which commonality of DoD and NASA supporting equipment can be derived.

Three international environments most grossly affecting the DoD establishment were therefore chosen, as illustrated on the following figure, and are shown as balance, instability, and confrontation between major powers. The first environment, which leads to the worlds number 1 and 2, is a condition in which a balance exists between the great international powers. This balance could be based on nuclear strength, resources, economic strength, or some combination of all three. The balance is not seen as labile or fleeting, but rather as a solid achievement in fact. Such a balance, as described in Volume III, could be achieved between five, six, or even more groupings of nations rather than in a bipolar orientation such as exists in the world today with the U.S. versus Russia. The international situation is therefore portrayed as stable, with the period of stability expected to last at least through the end of the century, with the small disadvantaged nations remaining small and disadvantaged and the large or powerful nations remaining large and powerful. No moves can be made by any major power which would greatly disrupt this overall balance due to real pressures from a concensus of the other powers, whether international peace treaties or pledges not to engage in cold war are honored or not.

The second international environment is an instability among the major powers in which there is great maneuvering in an attempt to continually gain advantage ideologically, economically, or physically. This leads to Worlds #3 and #4. Though it is not a situation of stability, it is a condition in which no real winner is expected to emerge in the next twenty-five years who would be so strong as to precipitate an international confrontation leading to general nuclear war in this time period.

Spectrum of Representative Scenarios

	WORLD #1	WORLD #2	WORLD #3	WORLD #4	WORLD #5	WORLD #6
INTERNATIONAL ENVIRONMENT:	BALANCE BETWEEN POWERS	BALANCE BETWEEN POWERS	INSTABILITY AMONG POWERS	INSTABILITY AMONG POWERS	CONFRONTATION WITH HOSTILE AXIS WAR IN 2000	CONFRONTATION WITH HOSTILE AXIS WAR IN 1990
DOMESTIC ENVIRONMENT:	ISOLATIONISM	CAPITAL EXPANSION	CONSERVATISM	INNOVATIVE EXPANSION	AMBIGUOUS ATTITUDES	NO-NONSENSE PREPAREDNESS
NATIONAL POLICIES:	NEO-POPULISM	NEO-MERCANTILISM	NEO-NEW DEAL	NEO-NEW FRONTIER	BOTH GUNS AND BUTTER	MOBILIZATION
DOMESTIC MOOD TOWARD:						
• TECHNOLOGY	• Mistrusted	• Exploited for Economic Return	• Discouraged	• Encouraged	• Encouraged if Common with Military	• Discouraged Unless Weapon-Related
• MILITARY	• Resented	• Tolerated	• Discouraged	• Exhorted	• Encouraged	• Seen as Only Hope
• SPACE	• Discouraged	• Accepted	• Neutral	• Encouraged - Seen as Vital	• Encouraged - Seen as Vital	• Discouraged Unless Near-Term and Weapon-Related
LIKELY BUDGET FOR SPACE:						
• MILITARY	Small (≪ 1B)	Small (≈ 1 B)	Medium (1-3 B)	Large (3-6 B)	Large (4-7 B)	Very Large (> 10 B)
• CIVILIAN	Small (< 1B)	Large (3-6 B)	Small (≈ 1 B)	Medium (≈ 3 B)	SM/Medium (1-3 B)	Small (< 1 B)
PLANNING HORIZON						
• MILITARY	Near-Term	Mid/Far-Term	Near-Term	Far-Term	Mid-Term	Near-Term
• CIVILIAN	Near-Term	Mid/Far-Term	Near-Term	Far-Term	Mid-Term	Near-Term

The third major environment is represented by an assumption that two or three of the major world powers form an alliance against the United States. For instance, this could be China and the Soviet Union after reconciliation, or Japan and China, or Japan and the Soviet Union, or all three. Such an alliance would very rapidly lead to a preemptive confrontation with the United States and to general nuclear war. It is assumed that the war would occur in the year 2000 in World #5, and in the year 1990 in World #6.

The domestic environment is much more complicated than the international one, in the sense that there is no simple set of adversaries which shapes national policy for survival; rather there are many factions pulling in diverse directions--economic, political, technological, ethnic, and ideological. For the purposes of this study, we chose to portray two extremes of internal attitudes of the people for Worlds #1 through #4, which are represented in trends towards isolationism and conservatism, as opposed to expansionistic, confident, mercantile trends. Thus in World #1 we see an internal trend toward isolationism, which combined with an international balance of power leads to a national policy outwardly manifested in something very near to the populist movement of the 1890-95 time period (these attitudes would now result in de facto isolationism and the refusal to assume international leadership). The domestic environment would include a distrust toward activities which require centralized government control. The emphasis would be on management by referendum instead. The military would be compelled to emphasize defense as versus offense. National ventures would have to appeal to the man in the street with immediate payoff as opposed to long-range economic aid, which would result in de-emphasis of long-range ventures in favor of practical utilization of available techniques. Large-scale projects would be financed largely through prior popular subscription. Under these circumstances, the general attitude of the public toward

technology might be viewed as one of mistrust, and toward space in general one of discouragement in favor of more understood and less flamboyant applications of technology. The military would likely be resented regardless of how small its budget, and its offensive capability severely limited. The entire domestic mood would likely result in repression and de-emphasis of high technology in favor of support of programs giving immediate relief or aid to the man in the street and yielding the maximum number of jobs.

Contrasted to such a world would be World #2 in which the international balance and relative climate of peace assumed to exist would be exploited by capital in vigorous expansion both domestically and internationally in something which might be called neo-mercantilism, resembling perhaps the golden decade of Japanese expansion in the 1955-65 time period. Under these situations, centralized (government) high technology activities would also be expected to prosper. Representative management rather than direct referendum would be used for effective organization.

The military would be tolerated and seen as a necessary stragetic deterrent to maintain the climate of peace as well as to maintain military and diplomatic options. Its expenditures would not be expected to be extreme, however, and projects common with the civil agencies would be encouraged. The view toward technology in general would be one in which all technologies would be viewed as candidates for exploitation for economic return. The attitude toward space would be accepting, when and where economic benefit could be shown to be the result. In addition, the climate of peace existing in the world would be conducive to scientific exploration and expansion of knowledge for its own sake as well as for its fallout on the economy.

In the first world, the likely budget for financing U.S. space projects is expected to be small, judging by the domestic mood toward technology, space, and the military. The planning horizon for programs is expected to be fairly near-term, with far-term projects mistrusted and discouraged. In contrast in World #2, while the military is still barely tolerated, civilian space is accepted and exploited. Under such conditions the military budget is expected to be fairly small, around one billion a year; however, the civilian budget is expected to be the largest of any scenario in this study - somewhere between three and six billion per year. (Note that while some of this money is sure to be returned to the investing capital or to result in increased production, only the outlays are shown in the budget.) The combination of internal and external environments leads to a mid-term or far-term planning horizon in World #2.

In Worlds #3 and #4 we have an unstable situation in the international scene combined with two different views of the domestic situation similar to those espoused in Worlds #1 and #2. World #3 leads directly to a domestic situation best described as a similarity to the "New Deal". Under these conditions, welfare and WPA-like projects would proliferate. The benefit is for the man-in-the-street. It is a negative view of progress in which the physical plant in industry is enlarged rather than modernized to cope with the demands, and the employment of people is in mind-numbing mass activity rather than in innovative enterprises. The military-industrial complex exists but does not flourish. Under such conditions, high technology lacks impetus or support; the military is somewhat discouraged; and the attitudes toward space are neutral. It is expected that in this internally negative and internationally unstable situation, the size of the military budget would be not unlike that of today's DoD space budget -- somewhere

between one and three billion -- whereas the civilian budget would be expected to be relatively small. The emphasis would be on near-term planning, with far-term projects deferred.

In World #4 a confident-innovative-expansionistic view internally combined with the maneuvering due to the external instabilities, channels activities in a positive direction very much as in World #2. New technology is innovative and new ventures proliferate. There is a prudent conservationism of U.S. resources tempered by an emphasis on increased allocation to R&D in exportable technical products and programs. The facilities of industrial plants are modernized rather than simply utilized and expanded, the modernization including production of technological specialties in which the U.S. is unexcelled. Rapid expansion is seen also in the production of industrial staples. Improvement is seen in communities and municipal facilities. Public utilities increase their service. Much of this is achieved through creative legislation directed toward constructive motivation of leadership people in the private sector as well as in government. Under these conditions, something very much akin to the New Frontier administration would emerge, in which technology in general and space in particular are encouraged and seen as a vital medium. The military is encouraged both in offense and defense capability, responding to the increased needs due to the international maneuvering. The space budgets under these conditions are likely to be quite large for the military, and for NASA about the same or slightly larger as today. The horizon for planners would be far-term, with innovative high technology systems meeting approval.

Now we come to Worlds #5 and #6. In both of these worlds there is a sure international confrontation with the hostile axis or coalition. In case of World #5, we assume a preemptive strike on the part of some enemy in the year 2000. In World #6 we assume

the strike to occur as early as the year 1990. Such a preemptive strike is to be expected whether the U.S. wants it or not and it is assumed that no amount of talk will prevent it. Although the exact nature of the enemy coalition would require further study, it is unimportant for this scenario. In World #5 the internal domestic environment can best be characterized as ambigious. There are negative as well as positive trends in balance. A similar situation might exist to that of immediate pre-World War II history in which the U.S. resolved not to become involved unless we were attacked. Under these conditions, there would be an attempt to maintain some order and some growth in the internal economy while viewing the externally mounting situation with great alarm but generally unwilling to mobilize fully against it. The dominant national policy would be to provide "both guns and butter" in a balanced proportion, recognizing that while war is inevitable it is a long way off, and that an entire generation cannot be occupied preparing for a war 25 years away without losing their resolve. The internal circumstances would lead to a national policy which would encourage technology providing it finds common civil and military use. It would encourage and even exhort the military to carefully prepare for the confrontation. Space would be seen as a vital medium and encouraged in both military and civilian activities, and common use of military and civil hardware, techniques, subsystems, etc., would see their peak in this scenario. Under this world condition, the yearly military budget could be expected to be quite large (between four and seven billion) in the 25-year period of interest. The civil budget would be expected to be quite small compared to that of World #2, for instance, though not very much different from that of today (in the order of one to three billion per year). The planning outlook would be mid-term with far-term projects deferred because of the uncertainty due to the impending war.

In contract to World #5, the World #6 domestic attitude is assured to be one of recognition of the impending doom resulting in no-nonsense preparedness to meet the

adversary. This, of course, can be seen as very similar to the U.S. attitude shortly after formally entering World War II. The national policy would be one of mobilization of all resources toward the impending conflict. In such a world centralized high technology activity would be mobilized for immediate final development of pre-planned military systems. Weapon systems would be deployed and proliferated for protection of vital industrial installations, population centers, and transportation arteries. The military would be seen as the only hope of survival of the nation in its currently recognized form. New technology would be discouraged unless the resulting developments were weapon related and of such form as to allow immediate military application. Use of space would be discouraged in contrast to more understood terrestrial operations, except near-term and weapon-related projects. The likely budget for the military would be extremely large (in excess of ten billion per year), whereas the civilian space budget would more than likely be very small and in every way subordinate to military requirements. The planning horizon would of necessity be very near-term.

The scenarios described above probably span the spectrum of international and domestic situations which will define the U.S. environment in the period 1980-2000. We take no position as to which world we are currently in, which world we think is most likely, or whether any world described is likely or realistic. However, it is reasonably fair to say that this spectrum is probably broad enough to include many of the dominant features of likely developments in international and domestic situations for the next 20-25 years; but the exact shape of those developments is not known, probably not predictable, and not useful to speculate about. It is the aim of this spectrum of scenarios to enable the generation of a set of program plans from which information may be extracted applicable to any future world which is likely

to exist. This spectrum of representative scenarios is thus utilized as the departure point for derivation of the program plans, and is central to the methodology adopted in this study for derivation of likely common needs for supporting space operations of NASA and DoD in the 1980-2000 time period.

SECTION 4

PLAN CONSTRUCTION DIRECTIVES

PLAN CONSTRUCTION DIRECTIVES

The alternate world scenarios described in the last section must be interpreted in terms of specific directions to the military and civilian national establishments. These establishments would guide their program plans to be responsive to the domestic and international situations as described by the alternate scenarios.

This section includes two types of directives based on the scenarios: one, the executive directives aimed at the military and civilian establishment leadership, and the other a more detailed set of directives such as might be issued by those leaders for the guidance of their planning organizations.

SECTION 4 (a)

EXECUTIVE DIRECTIVES FOR THE CIVILIAN SPACE PROGRAM MANAGERS

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In this chapter each alternate world scenario is interpreted both in a general and in a specific sense in its implications for the civilian space programs. The topics addressed in the general sense include the budget to be expended, the time-frame stability, the reliance on military programs, the emphasis to be placed on innovation, the emphasis to be placed on international programs, and the likely role of man in space. In the specific directives, the magnitude of effort in earth-oriented applications versus those of exploration, science, and in technology are specified. Each of these factors is interpreted for the particular world situation applicable to each of the six alternate worlds. As an example, technology activities might be expected to be very minimal in Worlds #1 and #6 whereas very large in World #2 and moderate in Worlds #4 and #5. The use of man in space is probably incompatible with the attitudes of World #1. In World #2, however, the role of man is large for exploration, science, and when otherwise justified; similarly in World #4. In World #6, man probably has a small role but only in areas supporting military applications. In World #1, though the total program is small, there is a reliance on military technology in order to maximize the dollar invested in space; whereas in World #2, military technology need not be utilized for civilian space programs unless it is very easy to do so, and parallel programs are to be expected rather than common programs. In contrast, in World #5 commonality although not required would be emphasized. In World #6, military technology would absorb practically all the available money, and civilian programs would have to rely on military technology or dual-role systems. The planetary exploration program would be non-existent in Worlds #1 and #6, very large in World #2, and moderate to small in the other worlds.

CIVILIAN SPACE PROGRAM EXECUTIVE DIRECTIVES

		WORLD #1	WORLD #2	WORLD #3	WORLD #4	WORLD #5	WORLD #6
Time Frame Stability		Status-quo for 25 yrs	Rapid growth for 25 yrs	Little progress for 25 yrs	Rapid growth for 25 yrs	War in 2000; limited growth for 25 yrs	War in 1990; further planning not possible
Planning Horizon/Space Budget		Near-term/<1B	Mid-/far-term/ 3-6B	Near-term/ 1B	Far-term/ 3B	Mid-term/ 1-3B	Near-term/<1B
New Starts		Few	Many, whenever economic payoff indicated	Few	Fairly many	Moderate number	None solely civilian
Reliance on Military Programs		Utilize military technology to max. extent	Emphasize common use, but reliance not required	Utilize military technology where practical	Common use encouraged but not required	Rely heavily on military programs	Rely totally on military or fallout
Emphasis on Innovation		Minimize	Emphasis for clear economic payoff	Minimize	Emphasize	Neutral	None
Emphasis on International Programs		Minimize	Emphasize, encourage	Discourage	Encourage	Ambiguous	None, except for communication between allies
Role of Man in Space		None	Large, whenever economically justified	Minimal	Moderate emphasis	Only if shared for military payoff	Only for military payoff
Earth-Oriented Applications	Materialistic	Small effort	Large effort	Moderate effort	Large effort	Moderate effort	Small effort, unless immediate military payoff
	Humanistic	Very small effort	Large effort	Small effort	Moderate effort	Small effort	Very small, if any
Exploration		None	Large effort	Essentially none	Moderate effort	Small effort	None
Science		Very small effort	Large effort	Small effort	Moderate effort	Moderate effort	Minimum, unless immediate military payoff
Technology		Minimum supporting activities	Large effort - lead the world	Small effort	Large effort	Moderate effort if common with military	Minimum, unless immediate military payoff

SECTION 4 (b)

MILITARY SPACE PROGRAM EXECUTIVE DIRECTIVES

MILITARY SPACE PROGRAM EXECUTIVE DIRECTIVES

In this section, the alternate world scenarios are interpreted for the leaders in the military establishment, with similar general considerations as those of the civilian directives such as number of new starts, reliance on civilian programs, and emphasis on innovation; but with the specifics being keyed to the very different functions of the military and the civil establishments. Thus the particular roles to be played by the strategic versus the tactical forces, versus those with responsibility for defense of the homeland are spelled out.

This page is only included in the classified version of this report.

SECTION 4 (c)

INSTRUCTIONS TO SPACE PROGRAM PLANNERS

The executive directives of the previous section must be interpreted further by the civilian and military leaders in order to form concrete instructions to their planning directorates, if program plans are to be put together consistent with the guidelines implicit in the six alternate world-scenarios previously defined. To this end, specific instructions for the space program planners were generated in seven explicit activity description sheets. The instruction sheets are shown following this page but the general content of the sheets is illustrated on the facing page.

There are seven sheets of instructions, one for each major category of civilian and military function ranging from civilian observations to military weaponry. Each sheet lists the magnitude of effort; the emphasis on near-, mid-, or far-term activity; and the degree of commonality with the other agency which is desired of the program element for each space function. The space functions are those described and identified in Volume III. Thus for example, the civilian observation functions have four major categories: observation of the surface, the ocean, the atmosphere, or space. These are broken down into observations of resources and pollution, boundaries, disasters, sea state and ocean physics, collision avoidance, weather, atmospheric physics, astronomy, geodetics, planetary exploration, and physics. For each of these functions the activity to be included in each of the program plans is described. The following seven sheets of space program planning instructions follow the format of the illustration and contain the specific instructions for the building of space program plans interpreting the implicit and explicit instructions contained in the definition of the six alternate world scenarios. A scanning of the seven sheets will show the specific differences reflecting the nature of the alternate worlds.

Instructions to Space Program Planners

MILITARY WEAPONS

MILITARY SUPPORT

MILITARY COMMUNICATIONS

MILITARY SURVEILLANCE

CIVILIAN SUPPORT

CIVILIAN COMMUNICATIONS

CIVILIAN OBSERVATION

FUNCTION		WORLD #1	WORLD #2	WORLD #6
Surface Observation	Resources/ Pollution	• Small Effort • Near-Term • Common With DOD Required	• Large Effort • Far-Term • Common Desired But Not Required	• Small Effort • Near-Term • Use DOD Only
	Boundary	~	~	~
	Disasters	~	~	~
Ocean Observation	Sea State, Ocean Physics	~	~	~
	Collision Avoidance	~	~	~
Atmosphere Observation	Weather	~	~	~
	Atm. Physics	~	~	~
Space Observation	Astronomy	~	~	~
	Geodetics	~	~	~
	Planetary Exploration	• Very Small Effort • Near-Term	• Large Effort • Far-Term	None
	Physics	~	~	~

SEVEN INSTRUCTION SHEETS

ACTIVITY DESCRIPTION - CIVILIAN OBSERVATION

FUNCTION		WORLD #1	WORLD #2	WORLD #3	WORLD #4	WORLD #5	WORLD #6
SURFACE OBSERVATION	RESOURCES, POLLUTION	• Small Effort • Near Term • Common	• Large Effort • Far Term • Common if Easy	• Small Effort • Near and Mid Term • Common if Practical	• Moderate Effort • Far Term • Common if Easy	• Moderate Effort • Mid Term • Common (Mil)	• Small Effort • Near Term • Common (Mil)
	BOUNDARY	• Moderate Effort • Near Term • Common	"	• Large Effort • Mid Term • Common if Practical	• Large Effort • Far Term • Common if Easy	• Moderate Effort • Mid Term • Common	• Small Effort • Near Term • Common
	DISASTERS	• Very Small Effort • Near Term • Common	"	• Small Effort • Near and Mid Term • Common if Practical	• Moderate Effort • Far Term • Common if Easy	• Small Effort • Mid Term • Common	• Very Small Effort • Near Term • Common
OCEAN OBSERVATION	SEA STATE, OCEAN PHYSICS	• Very Small Effort • Near Term • Common	"	"	"	• Moderate Effort • Mid Term • Common	"
	COLLISION AVOIDANCE	• Very Small Effort • Near Term • Common	"	"	"	• Small Effort • Mid Term • Common	"
ATMOSPHERIC OBSERVATION	WEATHER	• Small Effort • Near Term • Common	"	"	"	• Moderate Effort • Mid Term • Common	• Small Effort • Near Term • Common
	ATMOSPHERIC PHYSICS	• Very Small Effort • Near Term • Common	"	"	"	"	• Very Small Effort • Near Term • Common
	ASTRONOMY	"	"	"	"	"	"
SPACE OBSERVATION	GEODETICS	"	"	"	"	"	"
	PLANETARY EXPLORATION	• Very Small Effort • Near Term	• Large Effort • Far Term	• Small Effort • Near and Mid Term	• Moderate Effort • Far Term	• Moderate Effort • Mid Term	• No Effort
	PHYSICS	"	"	"	"	"	"

ACTIVITY DESCRIPTION - CIVILIAN COMMUNICATION

FUNCTION		WORLD #1	WORLD #2	WORLD #3	WORLD #4	WORLD #5	WORLD #6
INTERGOVERNMENT LINKS		• Small Effort • Near Term • Common	• Large Effort • Far Term • Common if Easy	• Small Effort • Near and Mid Term • Common if Practical	• Moderate Effort • Far Term • Common if Easy	• Moderate Effort • Mid Term • Common	• Small Effort • Near Term • Common
GOVERNMENT-TO-PEOPLE LINKS		• Very Small Effort • Near Term • Common	"	"	"	• Small Effort • Mid Term • Common	• Very Small • Near Term • Common
PEOPLE-TO-PEOPLE LINKS		"	"	"	"	"	"
INTRA GOVERNMENT LINKS	ROUTINE	• Small Effort • Near Term • Common	"	"	"	• Moderate Effort • Mid Term • Common	• Small Effort • Near Term • Common
	EMERGENCY	• Very Small Effort • Near Term • Common	"	"	"	• Large Effort • Mid Term • Common	• Large Effort • Near Term • Common
ENTERTAINMENT/ COMMERCIAL LINKS		• Small Effort • Near Term • Common	"	"	"	• Moderate Effort • Mid Term • Common	• Small Effort • Near Term • Common

ACTIVITY DESCRIPTION - CIVILIAN SUPPORT

FUNCTION		WORLD # 1	WORLD # 2	WORLD # 3	WORLD # 4	WORLD # 5	WORLD # 6
NAVIGATION	VEHICULAR	• Small effort • Near term • Common	• Large effort • Far term • Common if easy	• Small effort • Near & mid term • Common if practical	• Moderate effort • Far term • Common if easy	• Moderate effort • Mid term • Common	• Small effort • Near term • Common
	PERSONAL	• Very small effort • Near term • Common	"	"	"	• Small effort • Mid term • Common	• Very small effort • Near term • Common
TRANSPORTATION AID/CONTROL		"	"	"	"	"	"
ENERGY	DELIVERY	• Small effort • Near term • Common	"	"	"	• Moderate effort • Mid term • Common	• Small effort • Near term • Common
	MANAGEMENT	"	"	"	"	"	"
ENVIRONMENT MODIFICATION	ATMOSPHERE	"	"	"	"	"	"
	ILLUMINATION	"	"	"	"	"	"
DISPOSAL AND CONTROL OF WASTES		"	"	"	"	"	"
SPACE TRANSPORTATION SYSTEM DEVELOPMENT		"	"	• Moderate effort • Near & mid term • Common if practical	"	"	• No effort

Pages 41 through 44 are only included in the classified version of this report.

SECTION 5

PROGRAM PLANS

PROGRAM PLANS

This section addresses the construction of program plans responsive to the directives based on the alternate world scenarios and prepared from the data banks of functional system options found in Volume III. One program plan will be prepared for each functional category and each alternate future world. This section will begin with a brief review of the functional categorization of the program planning data as well as a brief review of the functional system options data bank, prior to presentation of the plans themselves.

The facing page contains the space functions in the civilian space program which were utilized in this report. The functions of observation, communications, and support are each sub-divided into major categories and each of those is sub-divided into the particular application-oriented subcategory best illustrating the use or application of the function. Thirty subcategories in all are included as the functions into which the civilian space programs will be categorized.

FUNCTIONS IN CIVILIAN SPACE PROGRAMS

FUNCTION	ORIENTATION	SPECIFIC ACTIVITY
OBSERVATION	SURFACE	Resources/Pollution; Boundaries; Disaster Areas
	OCEAN	Sea State/Ocean Physics; Collision Avoidance
	ATMOSPHERE	Weather; Atmosphere Physics
	SPACE	Astronomy; Geodetics; Planetary Exploration; Physics
COMMUNICATIONS	INTERGOVERNMENT LINKS	International; Diplomatic
	GOVERNMENT/PEOPLE LINKS	Voting/Polling
	PEOPLE/PEOPLE LINKS	Personal
	INTRAGOVERNMENT LINKS	Routine; Emergency
	ENTERTAINMENT/COMMERCIAL LINKS	T. V.; Mobile
SUPPORT	NAVIGATION	Vehicular; Personal
	TRANSPORTATION AID/CONTROL	Air/Sea/Ground
	ENERGY	Delivery; Management
	ENVIRONMENT MODIFICATION	Atmosphere; Weather; Illumination
	DISPOSAL AND CONTROL OF WASTES	Toxic/Radioactive
	NEW MEDIUM FOR RESEARCH AND MANUFACTURING	Dedicated; Incidental
	SPACE TRANSPORTATION DEVELOPMENT	Low; High; Planetary

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Pages 50 and 51 are omitted
because of security reasons.

In order to construct the space program plans, a data bank of system options as a function of time must be available. Such a data bank is found in Volume III. A particular sample is shown in the facing page for the purposes of illustrating the contents of the data bank. Seven sheets of system options exist in Volume III, one for each major category of function in military and civilian space activity. Each sheet contains the system options for near-term, midterm, and far-term space projects which apply for each subcategory of functions to be fulfilled. For the purposes of this report, we define near-term as 1980 $\pm$ five years, midterm as 1990 $\pm$ five years, and far-term as the year 2000 $\pm$ five years.

The functions in civilian observation are shown as an example, with the subcategories of surface observation for resources and pollution, and ocean observation detailed. The system options shown in the example are synthesized from the initiatives developed in Volume III of this report, the NASA and the DoD STS mission models, and other information from past NASA and DoD planning studies. The definitions of alternate or follow-on programs such as "LANDSAT-I, II, and III" were developed by the authors for this particular report and have no official significance. As an example of the system options, the near-term LANDSAT-I is assumed to be an operational Earth Resources Test satellite with somewhat improved readout and resolution from the current LANDSAT. LANDSAT-II is assumed to be a further improved LANDSAT-I with much more spatial and spectral resolution, incorporating an active on-board radar with a synthetic aperture array and real-time correlation of the passive and active signals either on board or off board. LANDSAT-III, which is a far-term program, is assumed similar to LANDSAT-II except for the addition of an active mode-locked laser radar with pico-second pulses for $\pm$ 0.3 mm ranging capability, and correlation between the active radar, the active lidar, and the passive

optics on board. The numbers at the bottom right-hand corner of the near-term, midterm, and far-term system options are the estimated costs of R&D, acquisition, and transportation for establishment of the required constellation of each of the system options, measured in billions of dollars. No operational costs are included in these numbers, and the numbers are assumed to be in constant 1975 dollars.

Similarly, SEASAT-I is assumed to be a low-power active radar similar to the current NASA SEASAT program, with data added from postulated DoD programs on specialized surveillance which are assumed to have a somewhat similar capability. In the midterm SEASAT-II, the power of the active radar is assumed to increase to 25 kW, with data added from more advanced postulated military surveillance satellites including imaging in optical-through-infrared, should such systems be simultaneously selected for a program plan. SEASAT-III is assumed to have an increase in power to 100 kW with the addition of a far-infrared laser radar for possible imaging through clouds, as well as data added from the far-term equivalent military space surveillance systems if available. Thus, the data bank of system choices for program plans shows capability increasing with time, and is composed of components ranging from single initiatives to combinations of various civilian and military initiatives.

Functional System Options Data Bank

MILITARY WEAPONS
MILITARY SUPPORT
MILITARY COMMUNICATIONS
MILITARY SURVEILLANCE
CIVILIAN SUPPORT
CIVILIAN COMMUNICATION
CIVILIAN OBSERVATION

Functions		Near-Term (1980±5)	Mid-Term (1990±5)	Far-Term (2000±5)
Surface Observation	Resources/ Pollution	LANDSAT-I • Operational ERTS • Improved Readout • Improved Resolution • More Channels 0.2	LANDSAT-II • Improved LANDSAT-I - More Resolution • Active On-Board Radar • Real-Time Correlation 0.4-0.6	LANDSAT-III • as LANDSAT-II • Add Active Laser - Picosecond Ranging • Correlate with Active Radar, Passive Optics 0.9-1.28
	Boundary	~	~	~
	Disasters	~	~	~
Ocean Observation		SEASAT-I • Low-Power Active Radar • Add Data From DOD 0.2	SEASAT-II • 25 kw Radar • Add Data From DOD 0.3-0.4	SEASAT-III • 100 kw Radar • Add Far-IR Laser Radar • Add Data From DOD
	Collision Avoidance	~	~	~
Atmosphere Observation	Weather	~	~	~
	Atm. Physics	~	~	~
Space Observation	Astronomy	~	~	~
	Geodetics	~	~	~
	Planet Exploration	~	~	~
	Physics	~	~	~

SEVEN
DATA SHEETS

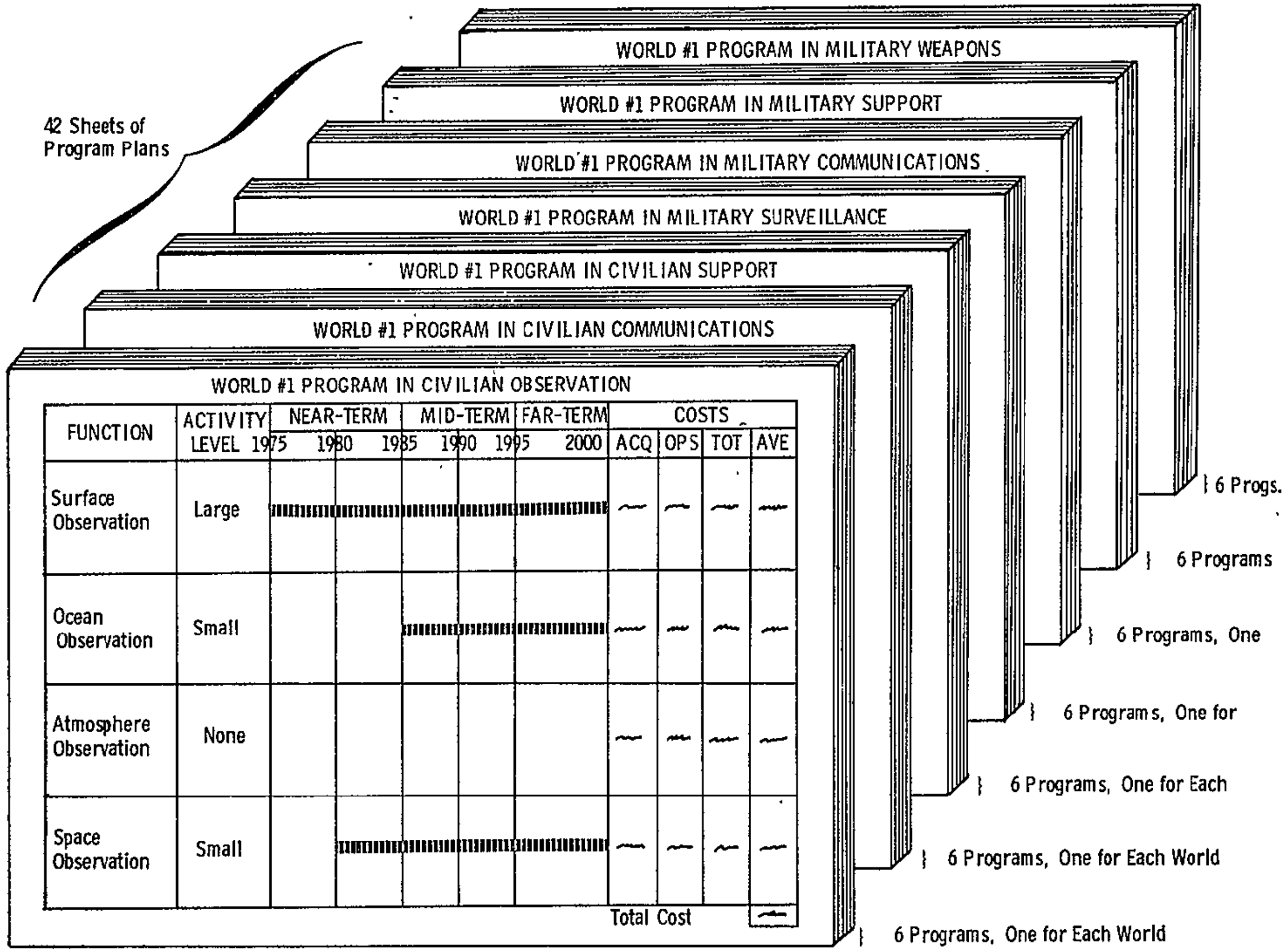
The program plans themselves occupy 42 data sheets, which are illustrated in the facing page and are shown in the 42 sheets immediately following this illustrative page. Each program plan is a sheet of paper in which the activity level and time sequencing of each subcategory of space function is shown. The choices are taken from the system options data bank illustrated in the previous page. Also shown are the costs of each of the programs in terms of acquisition, operations, total costs, and an average of the total costs divided by the number of years which the program plan spans (most of the plans span 25 years). This last average cost is derived in order that the summation of all the average costs of all the programs may be added for comparison to the average yearly budget permitted as described in each alternate world scenario.

One program plan sheet is developed for the conditions of World #1 for each of the seven major functional categories in the military and civilian programs, including military and civilian observations, military and civilian communications, military and civilian support, and military weaponry; and each repeated for the six alternate world scenarios. Thus, six program plans exist for each major functional category and 42 program plans are developed in all. The specific instructions in the planners' directives are followed and influence the choice of near-term, midterm, or far-term functional system option which is chosen for inclusion in a particular plan. Where there is a range of costs associated with a given system option, the instructed activity level is used to choose the funding for the program, which is shown in the cost columns of the program plans, a large activity level reflecting a choice of the larger of the budget estimates for that system option for that time frame.

An iterative procedure was followed, in which all the program plans were developed based on the guidelines of the "instructions." Then the costs were added up for all functional components of each of the program plans and compared with the budget assumptions appropriate for that world. If the resulting costs of the program plans so generated differed markedly from the assumed costs, the program plan was changed within the guidelines of the instructions, so as to coincide more closely with the budget assumptions. The assumptions made in derivation of the operational costs were based on a ground rule that each spacecraft requires either servicing or replacement every three years on orbit, and that the cost to service a spacecraft is one half the cost to replace it. Based on deployment of the near-term systems in 1980, they would be required to operate for 20 years. Midterm systems would be deployed in 1990 and would operate for ten years. Far-term systems would be deployed in the year 2000 and would have no operations time since 2000 is the cutoff for this study. Thus, the number of replacements or servicings needed during operations of near-term systems is six, for midterm systems is three, and for far-term systems is zero. Therefore, the cost of operations of near-term systems is assumed to be three times the acquisition cost; for midterm systems it is assumed to be twice the acquisition cost; and for far-term systems it is assumed to be zero. The costs of R&D must be added to each of the acquisition costs, of course, which is done in each program plan.

The following 42 pages present each of the program plans in its entirety. The first two program plans are somewhat more descriptive than the others and so some illustrative comments will be made regarding them.

Program Plans



This is the World #1 program plan in civilian observation. The program is seen to contain mostly near-term systems which are deployed and operated for the rest of the century, remembering that the National mood in World #1 was defined as anti-technology, anti-space, and highly isolationist, where the planning was all near-term for immediate fallout benefits to the population.

The programs in physics, geodetics, and astronomy are very small as are observations of the ocean state and atmospheric physics, and small programs are shown for resources, pollution, and weather, the rationale being that newfangled contraptions are not necessary with a return to inward-oriented basics, and that the first generation devices will yield adequate data. The only program which is even moderate sized is that of boundary observation because it is assumed that with the extreme trends to isolation a somewhat paranoid tendency may be developed in the population, calling for border security patrol. No programs are anticipated for disaster control or collision avoidance, collateral use of other programs being assumed. Planetary exploration is also nonexistent in such an inward-oriented society. The bulk of the programs simply continue current activities and some even at a quite reduced level.

The costs of this program plan reflect the low level of activity in World #1, with an average cost for the entire observation program for the civilian community being $150 million a year. This program is obviously very austere but appropriate for the definition of the world and domestic environment which it reflects.

World No. 1 Program in Civilian Observation

FUNCTION		ACTIVITY LEVEL	NEAR-TERM (1975–1985) / MID-TERM (1985–1995) / FAR-TERM (1995–2000)	COSTS ACQ.	OPS.	TOTAL	AVG.
SURFACE OBSERVATION	Resources Pollution	Small	LANDSAT-I ... OPERATE →	0.2	0.6	0.8	0.032
	Boundary	Moderate	Intrusion Alarm-I (ATS-F/G, Leased Comsat Channels, 10 W Sensors) →	0.1	0.3	0.4	0.016
	Disasters	–	No Program (Use ERTS, DSP)	---	---	---	----
OCEAN OBSERVATION	Sea State, Ocean Physics	Very Small	SEASAT-I (Low Power Radar) ... OPERATE →	0.2	0.3	0.5	0.020
	Collision Avoidance	–	No Program	---	---	---	----
ATMOSPHERIC OBSERVATION	Weather	Small	Continue TIROS, NIMBUS, SMS ... OPERATE →	---	0.6	0.6	0.024
	Atmospheric Physics	Very Small	Continue NIMBUS ... OPERATE →	---	0.2	0.2	0.008
SPACE OBSERVATION	Astronomy	Very Small	Continue OAO, OSO, Cancel HEAO →	---	0.3	0.3	0.012
	Geodetics	Very Small	Continue OGO, GEOS, Cancel all Others →	---	0.3	0.3	0.012
	Planetary Exploration	–	No Program	---	---	---	----
	Physics	Very Small	(See Separate Sheet)				0.028
			SUB TOTAL				0.152

World #2 is the civilian environment in which all civilian space programs flourish. The reason for this is that there is international peace coupled with a domestic spirit of exploiting the space medium to its fullest as well as satisfying intellectual and scientific curiosity. The activity level in each functional category and subcategory is seen to be large. Every program includes the near-term, midterm, as well as far-term system options from the data book of options in Volume III. As an example, in the resources and pollution area LANDSAT-I would be made operational as soon as possible and then augmented with or replaced by LANDSAT-II followed by LANDSAT-III in the far-term, the far-term options being approached in an evolutionary manner. Similar examples can be made for each and every one of the functional programs on this sheet. Note that the average cost of this program is $1.6 billion per year as contrasted with less than $150 million in the program for World #1. Such an outlay is appropriate, given the nature of the world as previously defined.

The following sheets contain the remainder of the 42 program plans, developed in a similar fashion to the World #1 and #2 programs in civilian observation just discussed. All these program plans were developed using careful consideration of the guidelines and instructions developed, and were iterated at least once to assure utilization of capabilities developed in other functions to the maximum. There is some duplication of systems as many of the system options are capable of fulfilling several functions, however, none of this duplication was removed due to lack of time and resources. Thus, the plans are conservative. The rest of the program plans will be shown without comment.

World No. 2 Program in Civilian Observation

FUNCTION		ACTIVITY LEVEL	NEAR-TERM / MID-TERM / FAR-TERM (1975 – 1980 – 1985 – 1990 – 1995 – 2000)	COSTS ACQ.	COSTS OPS.	COSTS TOTAL	COSTS AVG.
SURFACE OBSERVATION	Resources Pollution	Large	LANDSAT-I, II, III (Radar → Hi-power Radar → Picosecond Laser) →	1.2	2.4	3.6	0.144
	Boundary	Large	Intrusion Alarm-I, II, III (ATS-F → Multibeam Antenna → Very Large Antenna)	0.4	0.6	1.0	0.040
	Disasters	Large	Disaster Control-I, II, III, (SEASAT Data → + Forest Fire Det. / LANDSAT Data → + Military) + Laser & Radar	0.5	0.8	1.3	0.052
OCEAN OBSERVATION	Sea State, Ocean Physics	Large	SEASAT-I, II, III (Radar → Hi-power radar → laser far-IR, correlate) →	0.4	0.4	0.8	0.032
	Collision Avoidance	Large	Bistatic radar illuminator (1990–2000)	1.1	---	1.1	0.044
ATMOSPHERIC OBSERVATION	Weather	Large	TIROS, NIMBUS, SMS; • Improved NIMBUS • Hi-resolution Geosynchronous → Operate →	0.4	1.0	1.4	0.056
	Atmospheric Physics	Large	Profilometer (Laser radar) → (1985–2000)	0.5	0.8	1.3	0.052
SPACE OBSERVATION	Astronomy	Large	• OSO • Explorers; • HEAO • LST → • Large radio observatory • Focusing x-ray obs. • VLST • Large solar obs. → • 100 km radio telescope • 240 m. optical telescope	5.0	4.8	9.8	0.392
	Geodetics	Large	LAGEOS, GRAVSAT, MAGMON, GEOPAUSE and Improvements → Operate →	1.5	2.4	3.9	0.156
	Planetary Exploration	Large	(See Separate Sheet)				0.472
	Physics	Large	(See Separate Sheet)				0.168
			SUB TOTAL				1.608

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WORLD 3 PROGRAM IN CIVILIAN OBSERVATION

FUNCTION		ACTIVITY LEVEL	NEAR TERM 1975–1980–1985	MID TERM 1985–1990–1995	FAR TERM 1995–2000	COSTS ACQ.	OPS.	TOTAL	AVG.
SURFACE OBSERVATION	Resources Pollution	Small	LANDSAT-I (FCO1-1N)			0.20	0.60	0.80	0.032
	Boundary	Large	Intrusion Alarm-I, II, (FCO1-2N, FCO1-2M)			0.25	0.60	0.85	0.034
	Disasters	Small	Disaster Control-I (FCO1-3M)						
OCEAN OBSERVATION	Sea State, Ocean Physics	Small	SEASAT-I (FCO2-1N)			0.20	0.30	0.50	0.020
	Collision Avoidance		No Program			--	--	--	--
ATMOSPHERIC OBSERVATION	Weather	Small	TIROS, NIMBUS, SMS, METSAT-I (FCO3-1N)			0.15	0.30	0.45	0.018
	Atmospheric Physics		No Program						
SPACE OBSERVATION	Astronomy	Small	OAO, OSO, Astronomy-I (FCO4-1N)			1.00	0.90	1.90	0.076
	Geodetics	Small	OGD, GEOS, Geodetics-I (FCO4-2N)			0.80	1.20	2.00	0.080
	Planetary Exploration	Small	(See Separate Sheet)						0.198
	Physics	Small	(See Separate Sheet)						0.020
					SUB TOTAL				0.478

WORLD 4 PROGRAM IN CIVILIAN OBSERVATION

FUNCTION		ACTIVITY LEVEL	NEAR TERM (1975–1985) / MID TERM (1985–1995) / FAR TERM (1995–2000)	ACQ.	OPS.	TOTAL	AVG.
SURFACE OBSERVATION	Resources Pollution	Moderate	LANDSAT-I (FCO1-1N), LANDSAT-II (FCO1-1F)	0.20	0.60	0.80	0.032
	Boundary	Large	Intrusion Alarm-I, II, III (FCO1-2N, FCO1-2M, FCO1-2F)	0.40	0.60	1.00	0.040
	Disasters	Moderate	Disaster Control-I (FCO1-3M)				
OCEAN OBSERVATION	Sea State, Ocean Physics	Moderate	SEASAT-I (FCO2-1N)	0.20	0.30	0.50	0.020
	Collision Avoidance	Moderate	Collision Avoidance (FCO2-2F)	1.10	--	1.10	0.044
ATMOSPHERIC OBSERVATION	Weather	Moderate	TIROS, NIMBUS, SMS, METSAT-I (FCO3-1N)	0.15	0.30	0.45	0.018
	Atmospheric Physics	Moderate	Profilometer (FCO3-2M)	0.50	0.80	1.30	0.052
SPACE OBSERVATION	Astronomy	Moderate	OAO, OSO, Astronomy-I, II (FCO4-1N, FCO4-1M)	2.50	3.00	5.50	0.220
	Geodetics	Moderate	OGO, GEOS, Geodetics-I, II (FCO4-2N, FCO4-2M)	1.20	2.00	3.20	0.128
	Planetary Exploration	Moderate	(See Separate Sheet)				0.256
	Physics	Moderate	(See Separate Sheet)				0.060
			SUB TOTAL				0.870

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WORLD 5 PROGRAM IN CIVILIAN OBSERVATION

FUNCTION		ACTIVITY LEVEL	NEAR TERM 1975–1985	MID TERM 1985–1995	FAR TERM 1995–2000	COSTS ACQ.	OPS.	TOTAL	AVG.
SURFACE OBSERVATION	Resources Pollution	Moderate	LANDSAT-I (FCO1-1A)	(Use military)		0.20	0.60	0.80	0.032
	Boundary	Moderate	Intrusion Alarm-I, II (FCO1-2N, FCO1-2M)			0.25	0.60	0.85	0.034
	Disasters	Small	Disaster Control-I (FCO1-3M)						
OCEAN OBSERVATION	Sea State, Ocean Physics	Moderate	SEASAT-I (FCO2-1M)	(Use military)		0.20	0.30	0.50	0.020
	Collision Avoidance		No Program						
ATMOSPHERIC OBSERVATION	Weather	Moderate	TIROS, NIMBUS, SMS, METSAT-I (FCO3-1N)			0.15	0.30	0.45	0.018
	Atmospheric Physics		No Program						
SPACE OBSERVATION	Astronomy	Moderate	OAO, OSO, Astronomy-I, II (FCO4-1N, FCO4-1M)			2.50	3.00	5.50	0.220
	Geodetics	Moderate	OGO, GEOS, Geodetics-I, II, (FCO4-2N, FCO4-2M)			1.20	2.00	3.20	0.128
	Planetary Exploration	Moderate	(See Separate Sheet)						0.216
	Physics	Moderate	(See Separate Sheet)						0.060
					SUB TOTAL				0.728

WORLD 6 PROGRAM IN CIVILIAN OBSERVATION

FUNCTION		ACTIVITY LEVEL	NEAR TERM 1975–1980	NEAR TERM 1980–1985	MID TERM 1985–1990	MID TERM 1990–1995	FAR TERM 1995–2000	COSTS ACQ.	COSTS OPS.	COSTS TOTAL	COSTS AVG.
SURFACE OBSERVATION	Resources Pollution	—	(Use military)								
	Boundary	—	(Use Intrusion - I)								
	Disasters	—	No Program (Use military)								
OCEAN OBSERVATION	Sea State, Ocean Physics	—	No Program (Use military)								
	Collision Avoidance	—	No Program								
ATMOSPHERIC OBSERVATION	Weather	—	No Program (Use military)								
	Atmospheric Physics	—	No Program								
SPACE OBSERVATION	Astronomy	—	No Program								
	Geodetics	—	No Program								
	Planetary Exploration	—	No Program								
	Physics	—	No Program								
							SUB TOTAL				0

WORLD 1 PROGRAM IN CIVILIAN COMMUNICATIONS

FUNCTION		ACTIVITY LEVEL	NEAR TERM 1975–1985	MID TERM 1985–1995	FAR TERM 1995–2000	COSTS ACQ.	OPS.	TOTAL	AVG.
INTERGOVERNMENT LINKS		Small	Hotline-I, Intergovernment-I	(FCC1-C, FCC1-N)		0.25	0.45	0.70	0.028
GOVERNMENT TO PEOPLE LINKS			No Program			--	--	--	--
PEOPLE TO PEOPLE LINKS			No Program			--	--	--	--
INTRA GOVERNMENT LINKS	Routine	Small	Information Links	(FCC-4-1N		0.10	0.30	0.40	0.016
	Emergency		No Program			--	--	--	--
ENTERTAINMENT/COMMERCIAL LINKS			No Program			--	--	--	--
					SUB TOTAL				0.044

WORLD 2 PROGRAM IN CIVILIAN COMMUNICATIONS

FUNCTION		ACTIVITY LEVEL	NEAR TERM (1975–1985) / MID TERM (1985–1995) / FAR TERM (1995–2000)	COSTS ACQ.	COSTS OPS.	COSTS TOTAL	COSTS AVG.
INTERGOVERNMENT LINKS		Large	Hotline, Intergovernment-I, II, III (FCC1-C, FCC1-N, FCC1-M, FCC1-F)	0.80	1.50	2.30	0.092
GOVERNMENT TO PEOPLE LINKS		Large	Voting/Polling - I, II, III, Integrated (FCC2-N, FCC2-M, FCC2-F)	0.60	1.60	2.20	0.088
PEOPLE TO PEOPLE LINKS		Large	Personal/Co (FCC3-M, FCC3-F)	0.35	0.50	0.85	0.034
INTRA GOVERNMENT LINKS	Routine	Large	Information Links, Electronic Mail, Integrated Services (FCC4-1N, FCC4-1M, FCC4-1F)	0.55	0.60	1.15	0.046
	Emergency	Large	Emergency-I, II, Integrated (FCC4-2N, FCC4-2M, FCC4-2F)	0.70	1.20	1.90	0.100
ENTERTAINMENT/COMMERCIAL LINKS		Large	T.V. Broadcast-I, II, Integrated (FCC5-N, FCC5-M, FCC5-F)	0.70	1.20	1.90	0.100
			SUB TOTAL				0.460

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WORLD 3 PROGRAM IN CIVILIAN COMMUNICATIONS

FUNCTION		ACTIVITY LEVEL	NEAR TERM 1975–1985	MID TERM 1985–1995	FAR TERM 1995–2000	COSTS ACQ.	OPS.	TOTAL	AVG.
INTERGOVERNMENT LINKS		Small	Hotline, Intergovernment-I (FCC1-N)			0.25	0.45	0.70	0.028
GOVERNMENT TO PEOPLE LINKS		Small	Voting/Polling-I (FCC2-N)			0.05	0.15	0.20	0.008
PEOPLE TO PEOPLE LINKS		Small		Conferencing, Personal (FCC3-M)		0.35	0.50	0.85	0.034
INTRA GOVERNMENT LINKS	Routine	Small	Information Links, Electronic Mail (FCC4-1N)			0.10	0.30	0.40	0.046
	Emergency	Small	Emergency-I (FCC4-2N)			0.27	0.60	0.87	0.016
ENTERTAINMENT/COMMERCIAL LINKS			No Program			--	--	--	--
					SUB TOTAL				0.132

WORLD 4 PROGRAM IN CIVILIAN COMMUNICATIONS

FUNCTION		ACTIVITY LEVEL	NEAR TERM / MID TERM / FAR TERM (1975 1980 1985 1990 1995 2000)	COSTS ACQ.	OPS.	TOTAL	AVG.
INTERGOVERNMENT LINKS		Moderate	Hotline, Intergovernment-I, II (FCC1-C, FCC1-N, FCC1-M)	0.60	1.20	1.80	0.072
GOVERNMENT TO PEOPLE LINKS		Moderate	Voting/Polling-I, II (FCC2-N, FCC2-M)	0.28	0.40	0.68	0.028
PEOPLE TO PEOPLE LINKS		Moderate	Personal / Conferencing / Integr. (FCC3-M, FCC3-F)	0.67	0.50	1.17	0.047
INTRA GOVERNMENT LINKS	Routine	Moderate	Information Links, Electronic Mail-I, II (FCC4-1N, FCC4-1M)	0.40	0.60	1.00	0.040
	Emergency	Moderate	Emergency-I, II (FCC4-2N, FCC4-2M)	0.60	1.00	1.60	0.064
ENTERTAINMENT/COMMERCIAL LINKS		Moderate	T.V. Broadcast-I, II (FCC5-N, FCC5-M)	0.60	1.00	1.60	0.064
			SUB TOTAL				0.315

WORLD 5 PROGRAM IN CIVILIAN COMMUNICATIONS

FUNCTION		ACTIVITY LEVEL	NEAR TERM 1975–1980	NEAR TERM 1980–1985	MID TERM 1985–1990	MID TERM 1990–1995	FAR TERM 1995–2000	COSTS ACQ.	COSTS OPS.	COSTS TOTAL	COSTS AVG.
INTERGOVERNMENT LINKS		Moderate	Hotline, Intergovernment-I, II (FCC1-C, FCC1-N, FCC1-M)					0.60	1.20	1.80	0.072
GOVERNMENT TO PEOPLE LINKS		Small			Voting/Polling-I (FCC2-N)			0.05	0.15	0.20	0.008
PEOPLE TO PEOPLE LINKS		Small				Personal (FCC3-M)		0.35	0.50	0.85	0.034
INTRA GOVERNMENT LINKS	Routine	Moderate	Information System, Electronic Mail-I, II (FCC4-1N, FCC4-1M)					0.40	0.60	1.00	0.040
	Emergency	Large	Emergency-I, II, Integrated (FCC4-2N, FCC4-2M, FCC4-2F)					0.70	1.20	1.90	0.100
ENTERTAINMENT/COMMERCIAL LINKS		Moderate	T.V. Broadcast-I, II (FCC5-N, FCC5-M)					0.60	1.00	1.60	0.064
						SUB TOTAL					0.318

WORLD 6 PROGRAM IN CIVILIAN COMMUNICATIONS

FUNCTION		ACTIVITY LEVEL	NEAR TERM 1975 – 1980 – 1985	MID TERM 1985 – 1990 – 1995	FAR TERM 1995 – 2000	COSTS ACQ.	OPS.	TOTAL	15 YR AVG.
INTERGOVERNMENT LINKS		Small	Hotline, Intergovernment-I, II (FCC1-C, FCC1-N, FCC1-M)			0.50	1.00	1.50	0.100
GOVERNMENT TO PEOPLE LINKS			No Program			--	--	--	--
PEOPLE TO PEOPLE LINKS			No Program			--	--	--	--
INTRA GOVERNMENT LINKS	Routine	Small	Information Links (FCC4-1N)			0.10	0.30	0.40	0.027
	Emergency	Large	Emergency-I, II (FCC4-2N, FCC4-2M)			0.70	1.20	1.90	0.127
ENTERTAINMENT/COMMERCIAL LINKS			No Program			--	--	--	--
					SUB TOTAL				0.254

WORLD 1 PROGRAM IN CIVILIAN SUPPORT

FUNCTION		ACTIVITY LEVEL	NEAR TERM / MID TERM / FAR TERM (1975 1980 1985 1990 1995 2000)	COSTS			
				ACQ.	OPS.	TOTAL	AVG.
NAVIGATION	Vehicular	Small	(Use Military)	--	--	--	--
	Personal		No Program	--	--	--	--
TRANSPORTATION AID/CONTROL			No Program	--	--	--	--
ENERGY	Delivery		No Program	--	--	--	--
	Management	Small	Consumption Monitor-I (FCS3-2N)	0.15	0.30	0.45	0.018
ENVIRONMENT MODIFICATION	Atmosphere		No Program	--	--	--	--
	Weather		No Program	--	--	--	--
	Illumination		No Program	--	--	--	--
DISPOSAL AND CONTROL OF WASTES		Moderate	Nuclear Waste-I (FCS5-N, FCS5-M)	0.25	0.30	0.55	0.022
NEW MEDIUM FOR RESEARCH AND MANUFACTURING			No Program	--	--	--	--
TRANSPORT DEVELOPMENT		Small	Shuttle/IUS/TUG				0.200
			SUB TOTAL				0.240

WORLD 2 PROGRAM IN CIVILIAN SUPPORT

FUNCTION		ACTIVITY LEVEL	NEAR TERM (1975–1985)	MID TERM (1985–1995)	FAR TERM (1995–2000)	COSTS ACQ.	OPS.	TOTAL	AVG.
NAVIGATION	Vehicular	Large	Develop Civilian GPS			0.4	0.9	1.3	0.052
	Personal	Large	Personal Navigation I, II, III (FCS1-2N, FCS1-2M, FCS2-P)			0.4	0.6	1.0	0.040
TRANSPORTATION AID/CONTROL		Large	Transportation I, II, III (FCS2-N, FCS2-M, FCS2-F)			2.3	2.0	4.3	0.172
ENERGY	Delivery	Large	Energy Delivery I (FCS3-1F)			15.0	--	15.0	0.600
	Management	Large	Energy Management I, II (FCS3-2N, FCS3-2M)			1.0	1.4	2.4	0.096
ENVIRONMENT MODIFICATION	Atmosphere	Large		Ozone Layer - I, II (FCS4-3M, FCS4-3F)		2.0	2.8	4.8	0.192
	Weather		No Program			--	--	--	--
	Illumination	Large		Illumination-I, II (FCS4-3M, FCS4-3F)		3.5	2.0	5.50	0.220
DISPOSAL AND CONTROL OF WASTES		Large	Waste Disposal I, II, III (FCS5-N, FCS-5M, FCS5-F)			0.6	0.4	1.0	0.040
NEW MEDIUM FOR RESEARCH AND MANUFACTURING			No Program			--	--	--	--
TRANSPORT DEVELOPMENT		Large	Shuttle/TUG/SSTD/SEPS/LLV/Laser/Large TUG/ Large SEPS						1.200
					SUB TOTAL				2.612

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WORLD 3 PROGRAM IN CIVILIAN SUPPORT

FUNCTION		ACTIVITY LEVEL	NEAR TERM (1975–1985)	MID TERM (1985–1995)	FAR TERM (1995–2000)	COSTS ACQ.	COSTS OPS.	COSTS TOTAL	COSTS AVG.
NAVIGATION	Vehicular	Small	(Use Military)			--	--	--	--
NAVIGATION	Personal	Small	Personal Nav-I (FCS1-2N)			0.10	0.15	0.25	0.010
TRANSPORTATION AID/CONTROL		Small	Aerosat, Navsat, GPS (Initial)			0.10	0.15	0.25	0.010
ENERGY	Delivery		No Program			--	--	--	--
ENERGY	Management	Small	Management-I (FCS3-2N)			0.15	0.30	0.45	0.018
ENVIRONMENT MODIFICATION	Atmosphere		No Program			--	--	--	--
ENVIRONMENT MODIFICATION	Weather		No Program			--	--	--	--
ENVIRONMENT MODIFICATION	Illumination		No Program			--	--	--	--
DISPOSAL AND CONTROL OF WASTES		Small	Nuclear Waste-I (FCS5-N, FCS5-M)			0.25	0.30	0.55	0.022
NEW MEDIUM FOR RESEARCH AND MANUFACTURING			No Program			--	--	--	--
TRANSPORT DEVELOPMENT		Moderate	Shuttle/IUS/TUG/SSTD/SEPS						0.600
					SUB TOTAL				0.660

WORLD 4 PROGRAM IN CIVILIAN SUPPORT

FUNCTION		ACTIVITY LEVEL	NEAR TERM (1975–1985)	MID TERM (1985–1995)	FAR TERM (1995–2000)	COSTS ACQ.	COSTS OPS.	COSTS TOTAL	COSTS AVG.
NAVIGATION	Vehicular	Moderate	(Use Military)			--	--	--	--
NAVIGATION	Personal	Moderate	Personal Nav-I, II			0.40	0.60	1.00	0.040
TRANSPORTATION AID/CONTROL		Moderate	Transportation-I, II	III		2.00	1.20	3.20	0.128
ENERGY	Delivery	Moderate	Develop but don't Deploy			1.00	--	1.00	0.040
ENERGY	Management	Moderate	Management-I, II, Nuclear Fuel Locator Energy level/consumption monitor			0.80	1.20	2.00	0.080
ENVIRONMENT MODIFICATION	Atmosphere	Moderate		Ozone Layer-I		1.60	0.50	2.10	0.084
ENVIRONMENT MODIFICATION	Weather		No Program			--	--	--	--
ENVIRONMENT MODIFICATION	Illumination	Moderate		Illumination-I		1.10	1.60	2.70	0.108
DISPOSAL AND CONTROL OF WASTES		Moderate	Waste Disposal-I, II			0.25	0.30	0.55	0.022
NEW MEDIUM FOR RESEARCH AND MANUFACTURING			No Program			--	--	--	--
TRANSPORT DEVELOPMENT		Moderate	Shuttle/IUS/TUG/SSTO/SEPS						0.600
					SUB TOTAL				1.102

World No. 5 Program in Civilian Support

FUNCTION		ACTIVITY LEVEL	NEAR-TERM / MID-TERM / FAR-TERM (1975 1980 1985 1990 1995 2000)	COSTS ACQ.	OPS	TOTAL	AVG.
NAVIGATION	Vehicular	Moderate	(Use Military)	---	---	---	----
	Personal	Small	Personal Nav-I (1 mile user accuracy, 200ft satellite)	0.10	0.15	0.25	0.010
TRANSPORTATION AID/CONTROL		Small	(Use Military)	---	---	---	----
ENERGY	Delivery	–	No Program	---	---	---	----
	Management	Moderate	Consumption Monitor - I, II; • Optical energy Consumption Meter • Nuclear Fuel Locator	0.80	1.20	2.00	0.080
ENVIRONMENT MODIFICATION	Atmosphere	–	No Program	---	---	---	----
	Weather	–	No Program	---	---	---	----
	Illumination	Moderate	(Use Military)	---	---	---	----
DISPOSAL AND CONTROL OF WASTES		Moderate	Waste Disposal I, II; • Space debris sweeper • Experimental Nuclear waste disposer	0.25	0.30	0.55	0.022
NEW MEDIUM FOR RESEARCH AND MANUFACTURING		–	No Program	---	---	---	----
TRANSPORT DEVELOPMENT		Moderate	Shuttle/IUS/TUG/SSTO/SEPS				0.600
			SUB TOTAL				0.712

WORLD 6 PROGRAM IN CIVILIAN SUPPORT

FUNCTION		ACTIVITY LEVEL	NEAR TERM 1975 1980 1985	MID TERM 1985 1990 1995	FAR TERM 1995 2000	COSTS ACQ.	OPS.	TOTAL	AVG.
NAVIGATION	Vehicular	Small	(Use Military)						
	Personal	Very Small	(Use Military)						
TRANSPORTATION AID/CONTROL		Very Small	(Use Military)						
ENERGY	Delivery		No Program						
	Management		No Program						
ENVIRONMENT MODIFICATION	Atmosphere		No Program						
	Weather		No Program						
	Illumination	Small	(Use Military)						
DISPOSAL AND CONTROL OF WASTES			No Program						
NEW MEDIUM FOR RESEARCH AND MANUFACTURING			No Program						
TRANSPORT DEVELOPMENT			Cancel Shuttle/IUS						
				SUB TOTAL					0

WORLD 1 PROGRAM IN PHYSICS AND EXPLORATION SYSTEMS

FUNCTION	ACTIVITY LEVEL	1980 1985 1990 1995 2000	COSTS ACQ.	OPS.	TOTAL	AVG.
INNER PLANETS/SUN	Very Small	Continue Helios -- No New Starts	--	--	--	--
OUTER PLANETS	Very Small	Continue Current Programs -- No New Starts	--	--	--	--
COMETS/ASTEROIDS		No Program	--	--	--	--
PHYSICS	Very Small	Continue Explorers -- No New Starts	--	0.7	0.7	0.028
		SUB TOTAL				0.028

WORLD 2 PROGRAM IN PHYSICS AND EXPLORATION SYSTEMS

FUNCTION	ACTIVITY LEVEL	1980 1985 1990 1995 2000	COSTS ACQ.	OPS.	TOTAL	AVG.
INNER PLANETS/SUN	Large	Full Program: FCP1-N Through FCP1-F	2.3	3.6	5.9	0.236
OUTER PLANETS	Large	Full Program: FCP2-N Through FCP2-F	2.6	2.0	4.6	0.184
COMETS/ASTEROIDS	Large	Full Program: FCP3-N Through FCP3-F	0.7	0.6	1.3	0.052
PHYSICS	Large	Full Program: FCP4-N Through FCP4-F	2.2	2.0	4.2	0.168
		SUB TOTAL				0.640

WORLD 3 PROGRAM IN PHYSICS AND EXPLORATION SYSTEMS

FUNCTION	ACTIVITY LEVEL	1980 – 1985 – 1990 – 1995 – 2000	COSTS ACQ.	OPS.	TOTAL	AVG.
INNER PLANETS/SUN	Small	Near Term Only: FCP1-N	1.00	1.50	2.50	0.100
OUTER PLANETS	Small	Near Term Only: FCP2-N	0.90	1.20	2.10	0.084
COMETS/ASTEROIDS	Small	Near Term Only: FCP3-N	0.20	0.15	0.35	0.014
PHYSICS	Small	Near Term Only: FCP4-N	0.30	0.30	0.50	0.020
		SUB TOTAL				0.218

WORLD 4 PROGRAM IN PHYSICS AND EXPLORATION SYSTEMS

FUNCTION	ACTIVITY LEVEL	1980–2000	COSTS ACQ.	OPS.	TOTAL	AVG.
INNER PLANETS/SUN	Moderate	Medium Program: FCP1-N, FCP1-M	1.5	2.0	3.5	0.140
OUTER PLANETS	Moderate	Medium Program: FCP2-N, FCP2-M	1.2	2.0	3.2	0.088
COMETS/ASTEROIDS	Moderate	Medium Program: FCP3-N, FCP3-M	0.3	0.4	0.7	0.028
PHYSICS	Moderate	Medium Program: FCP4-N, FCP4-M	0.7	0.8	1.5	0.060
		SUB TOTAL				0.316

WORLD 5 PROGRAM IN PHYSICS AND EXPLORATION SYSTEMS

FUNCTION	ACTIVITY LEVEL	1980 – 1985 – 1990 – 1995 – 2000	COSTS ACQ.	OPS.	TOTAL	AVG.
INNER PLANETS/SUN	Small	Small Program: FCP1-N	1.0	1.5	2.5	0.100
OUTER PLANETS	Small	Medium Program: FCP2-N, FCP2-M	1.2	2.0	3.2	0.088
COMETS/ASTEROIDS	Small	Medium Program: FCP3-N, FCP3-M	0.3	0.4	0.7	0.028
PHYSICS	Moderate	Medium Program: FCP4-N, FCP4-M	0.7	0.8	1.5	0.060
		SUB TOTAL				0.276

WORLD 6 PROGRAM IN PHYSICS AND EXPLORATION SYSTEMS

FUNCTION	ACTIVITY LEVEL	1980	1985	1990	1995	2000	COSTS			
							ACQ.	OPS.	TOTAL	AVG.
INNER PLANETS/SUN										
OUTER PLANETS			NO PROGRAM							
COMETS/ASTEROIDS										
PHYSICS										
					SUB TOTAL					0

Pages 86 through 109 are omitted
because of security reasons.

The average yearly cost of each program plan for each world number was tabulated at the time of composition of the program plans. The average cost assumes that the peaks in funding can be appropriately spaced either by choice of the start and stop times of various programs and their phasing, or by some imaginative arrangement between Congress and the financial community such that the peaks are underwritten and amortized into all the years where less funding might otherwise be required. These average costs are compared on the facing page with the average yearly budgets assumed during the definition of each world number. The costs shown were finalized after two iterations. It is seen that the program costs compare fairly well with the assumed budgets for each world number, well enough for the purposes of this study, since it is to be emphasized that no advocacy of any particular world is implied anywhere in this exercise. Nor is it assumed that any particular future world will occur or is more realistic than any other. Suffice it to say that the program plans defined by the 42 sheets appear representative of reasonable programs for the Worlds #1 through #6 as defined, and that their costs are relatively well matched with the assumed budgets.

A second conclusion stems from the absolute magnitudes of the costs of the program plans of Worlds #1 through #6. It is to be noted (again assuming that the peak costs can be amortized into the total time period of this program), that the largest civilian space program which deploys every single system identified in the 1973 NASA Mission Model, every system concept identified as one of the initiatives in Volume II of this study, and other initiatives as well requires an average budget of less than $5 billion per year. This compares with an

average budget for programs of about $3 billion per year today. It is seen, therefore, that contrary to first impressions, less than a two-fold increase in the funding for space would allow the fielding of every space program initiative and the entire mission model, yielding fantastic increases in performance in every functional area. Similarly, for the military, Worlds #4 and #5 represent the largest military budgets with the acquisition of the largest number of large and far-term systems (short of a catastrophic condition such as faced in World #6). For these worlds about $5 billion a year total budget compared to today's budget of about $2 billion will secure fantastic increases in performance in every functional category. Ten billion dollars a year average for both civil and military space would buy practically all systems identified by the military and by the civilian community and by the initiatives of this study, which is a noteworthy statement in itself. Of course World #6 requires increased funding due to the imminent nuclear war.

Another way to view the program costs is that a continuation of the current military space budget of about $2 billion would allow response to world conditions represented somewhere between Worlds #1 and #4. For the case of the civilian programs, the current level of funding of $3 billion, if continued for 25 years, would be adequate to meet the conditions of Worlds #1, #3, #5, and #6.

A different way of assessing a budget of $5 billion a year over 25 years is that the total money spent will be $125 billion, which is a lot of money and can buy many space systems.

YEARLY PROGRAM COSTS[1], BILLIONS

FUNCTIONS		WORLD NUMBER 1	2	3	4	5	6
MILITARY	OBSERVATION	0.036	0.246	0.342	1.58	1.11	1.84
	COMMUNICATIONS	0.052	0.14	0.247	0.572	0.344	0.4
	SUPPORT	0	0.138	0.158	0.66	0.439	4.89
	WEAPONS	0	0.036	0.68	2.23	3.47	6.17
	TOTAL	0.088	0.56	1.43	5.03	5.36	13.4
	ASSUMED BUDGET	≪1.0	≈ 1.0	1-3	3-6	4-7	>10
CIVILIAN	OBSERVATION	0.152	1.6	0.478	0.87	0.728	0
	COMMUNICATIONS	0.044	0.46	0.132	0.315	0.318	0.254
	SUPPORT	0.24	2.61	0.66	1.1	0.712	0
	TOTAL	0.436	4.67	1.27	2.28	1.76	0.254
	ASSUMED BUDGET	< 1	3-6	≈ 1	≈ 3	1-3	< 1

[1]COSTS SHOWN AVERAGED OVER 25 YEARS (1975-2000)
(EXCEPT 15 YEARS (1975-1990) FOR WORLD #6

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SECTION 6

SUPPORTING NEEDS

SUPPORTING NEEDS

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The supporting needs of each of the space programs developed in the previous section were extracted in each of the building block and technology categories illustrated in the facing page. The supporting needs were divided into building blocks and technologies. The choices for low orbit transportation included an expendable booster (probably like the T-III), the Space Shuttle, and a large lift vehicle of about five to ten times the lift capability of the shuttle. The choices for high orbit or transfer orbit transportation systems included the interim upper stage and the full capability tug (lumped into one category), a much larger tug with the option for a manned capsule front end, the 25 kW Solar Electric Propulsion System, a much larger Solar Electric stage perhaps five to ten times the power level, and a nuclear stage for those orbital operations which require extensive and frequent maneuvering. The orbital assembly and servicing stages, the support facilities, and the technologies required for support for the on-orbit operations, as well as the payloads themselves make up the remainder of the classes.

The following six pages present the support requirements, shown as the total number of mission opportunities for each category as a function of the world number in the scenario. The judgment for inclusion or deletion of any particular initiative was passed in the last section with the preparation of the program plans. These numbers of mission opportunities reflect such judgment.

BUILDING BLOCK AND TECHNOLOGY CATEGORIES

BUILDING BLOCKS	TECHNOLOGIES
LOW ORBIT TRANSPORTATION	Large Optics and Mirrors
Expendable Booster	Large RF Antennas
Shuttle	High Power/Energy Sources
Large Lift Vehicle (LLV)	High Power Radar
HIGH ORBIT/TRANSFER TRANSPORTATION	High Energy Lasers
IUS/TUG	Manned Orbital Assembly Techniques
Large/Manned Tug	Precise Pointing and Tracking
SEPS	LSI Computers/Processors
Large SEPS	CCD Focal Planes
Nuclear	Cryogenic Refrigerators
ORBITAL ASSEMBLY AND SERVICING STAGES	
Automated Servicing Unit	
Manned Servicing Unit	
Shuttle-Attached Manipulator	
Free-Flying Teleoperator	
ORBITAL SUPPORT FACILITIES	
Assembly and Maintenance Yard	
Warehouse	
Fabrication	
Research Laboratory	
Universal Test Satellite	

The sum of all the civilian and military missions (initiatives) in which there are opportunities for utilization of each class of booster is shown as a function of the world number for the alternate scenarios. These were developed by summing the support needs of each initiative called for in each program plan. The format for presentation was chosen as straight lines connecting the data points for each of the world numbers, even though it is recognized that the data only exists for each discrete world number, since the connecting lines are useful for pictorial representation and for trend extrapolation. This graph as well as the following ones are plotted for the combination of both civilian and military opportunities and for the entire time frame from 1980 to the year 2000, i.e., incorporating the near-term, midterm, and far-term program opportunities. It is to be emphasized that this graph as well as the following ones represents mission opportunities, rather than a traffic model, the number of flights required of each booster (for instance) being far greater than the number of mission opportunities for its use.

A cursory analysis of the data on the facing page indicates that the shuttle is a versatile, high demand booster and will continue to be so through the end of the century, compared to an expendable or a larger launch vehicle, and continues to be very much in demand regardless of the nature of the future world facing us within the choices of the alternate world scenarios. The opportunities for utilization of the shuttle are many and relatively constant for Worlds #2 through #5 inclusive, being far smaller for World #1 and for World #6, which is to be expected since Worlds #2 through #5 are more moderate views of the future calling for greater numbers of space systems. World #1 is a very austere world for the military and civilians, results in a small number of payloads, and therefore

opportunities, for any booster. In World #6 the civilian opportunities drop off drastically, most of the opportunities shown being for military operations facing up to the war in 1990. The ground rule for requirements for a larger lift vehicle than the shuttle was established rather arbitrarily in the early part of the study in the following way: if a particular space program or initiative required more than about 100 shuttle flights to establish the system, a larger lift vehicle was indicated; otherwise the shuttle was deemed an adequate booster.

Data such as presented in the facing page cannot be used by itself to make a case for not developing a large lift vehicle or for phasing out expendable boosters, because the nature of the programs requiring such boosters and their relative priorities must also be addressed. It is clear from this chart, however, that the shuttle is an extremely versatile, high demand, well thought out program of great utility, even though many of the payloads which are assumed flown in the future worlds were not conceived at the time the shuttle design was definitized.

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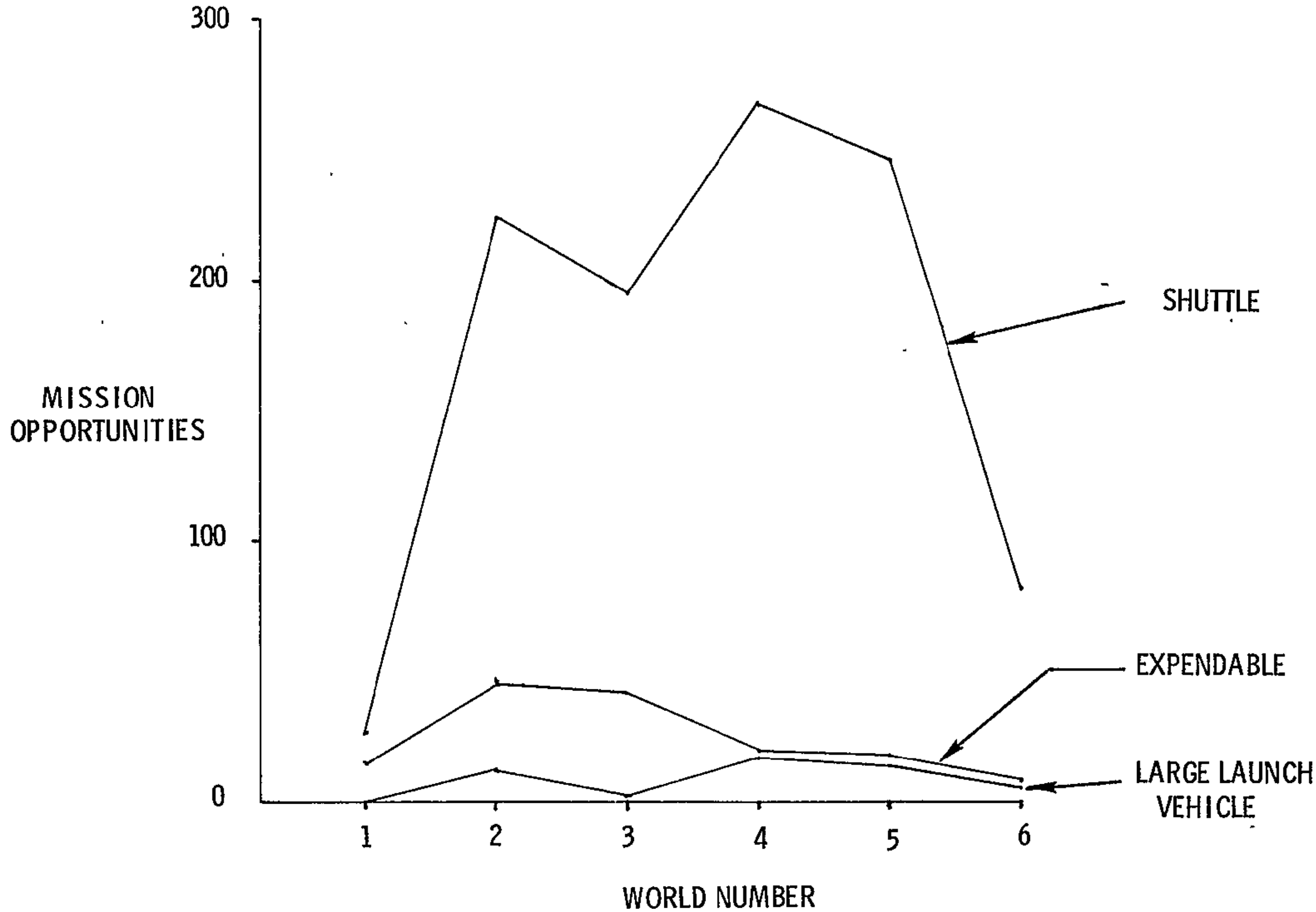
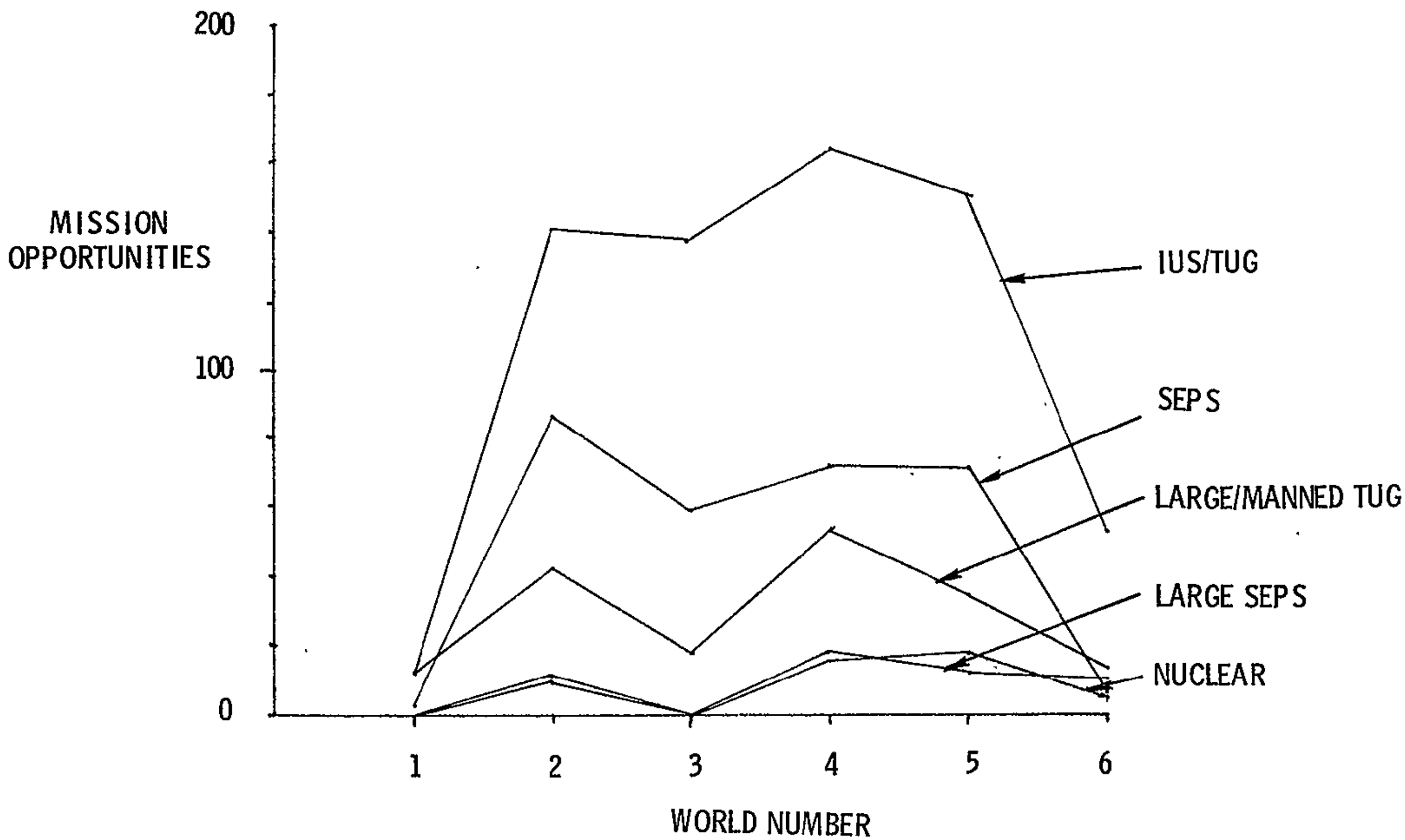
MISSION OPPORTUNITIES FOR LOW EARTH ORBIT TRANSPORTATION



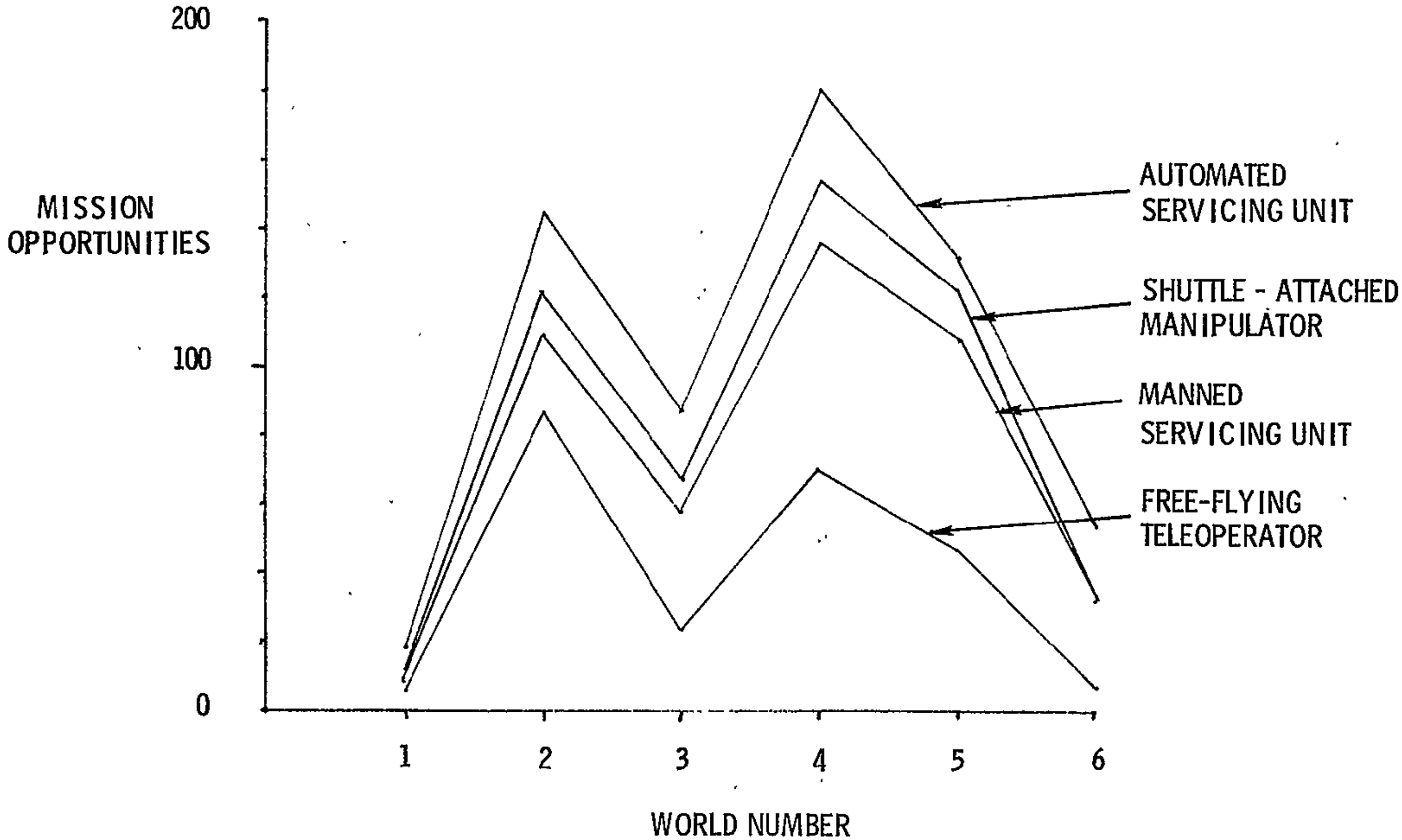
This graph indicates that the IUS and Full Capability Tug are desirable developments for which the demand exceeds all other high orbit or transfer transportation devices for most of the worlds considered. The IUS and FCT were lumped into one class of vehicle under the assumption that either or both would be available during the greater portion of the rest of the century, or that some single vehicle of similar capability would be. The 25 kW Solar Electric Propulsion Stage is next, with a larger version of the tug with a manned front end being next in line. The same trend is evident as for the low orbit transportation case: that most of the more moderate versions of the future world tend to have a relatively constant call for space supporting vehicles, with a small call in World #1 reflecting the austere view of the world domestically and with World #6 reflecting primarily a military call for near-term space systems. The total number of opportunities for an upper stage of some sort are about half of those requiring low altitude boost. The number of missions in which any particular upper stage is required is somewhat smaller than the number of opportunities shown, since a fair number of mission requirements can be met by a choice of several upper stage options, and all possible candidates contributed to the mission opportunities.

MISSION OPPORTUNITIES FOR HIGH ORBIT/TRANSFER TRANSPORTATION

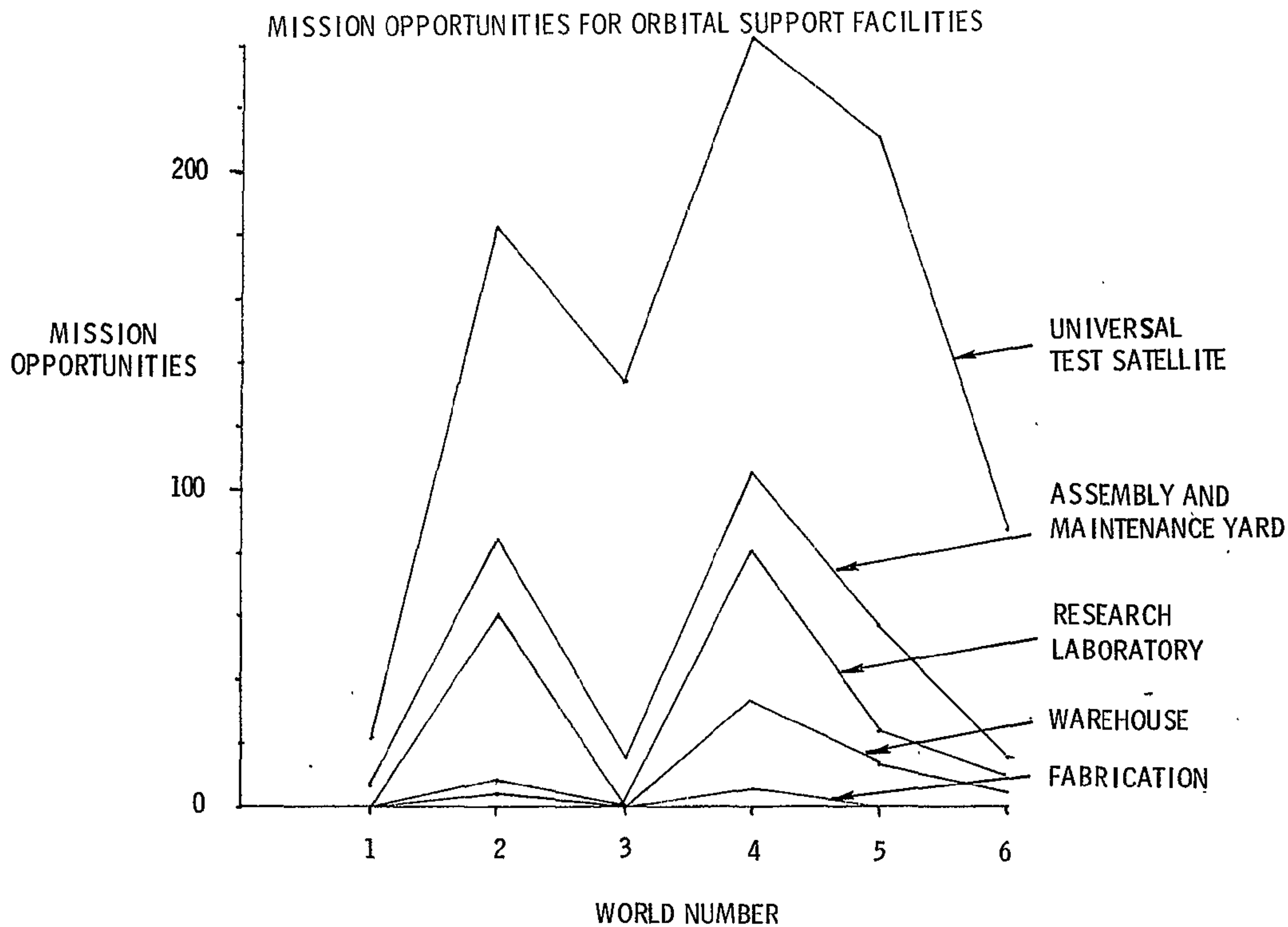


A similar trend is evident in this as well as in the following graphs where the number of mission opportunities for orbital assembly and servicing stages is seen to peak in the moderate worlds. A characteristic not evident to the degree in previous graphs, however, is the peaking of the demand for these stages in Worlds #2 and #4. The reason for this peaking is that World #2 has the largest number of mission opportunities for the civilian community whereas World #4 has the largest number of mission opportunities for the military community, and the accentuation of the peaks compared to World #3 is due to the greater percentage of large, heavy missions in Worlds #2 and #4 which require some form of orbital assembly and servicing. It is also seen that a fairly large number of mission opportunities exist for assembly and servicing units of some type independent of what the future will actually turn out to be. The ground rule used for specifying automated versus manual units was that no choice was made unless the mission clearly required man or clearly had to be unmanned (such as a flight in the radiation belts). Thus, the manned opportunities nearly equal the unmanned ones, the choice being left to those who might wish to develop specific initiatives further.

MISSION OPPORTUNITIES FOR ORBITAL ASSEMBLY AND SERVICING STAGES



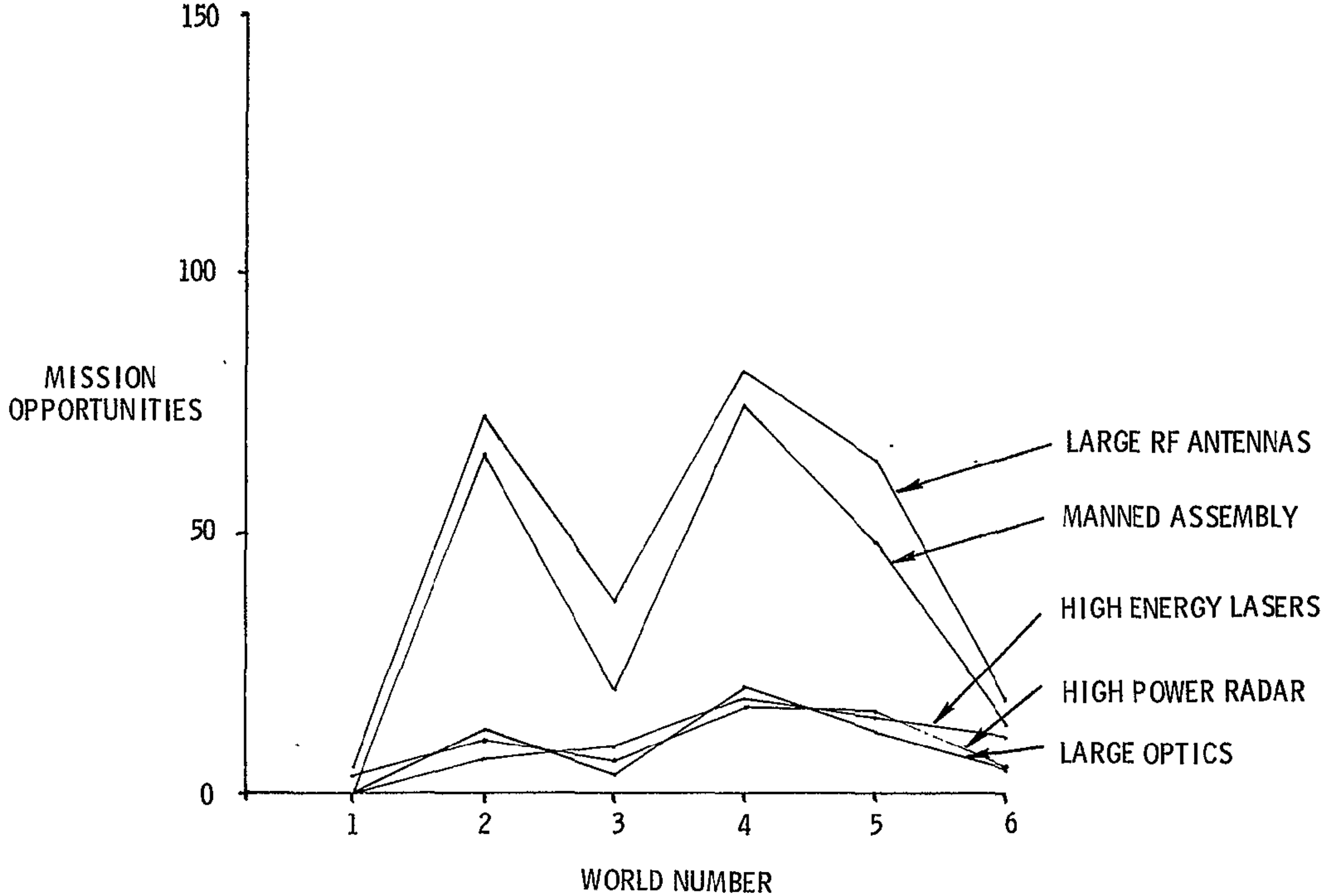
In this graph it is seen that a very large number of mission opportunities exist for a universal test satellite, which might be represented by a small satellite vehicle used in conjunction with the shuttle or used in a sortie mode in the process of development of satellites. This could be considered an outgrowth of the current STP program of the Air Force. Assembly and maintenance yards are a generic term which is used to describe functionally-oriented space stations. These are required in Worlds #2 and #4 in particular, as is a research laboratory of some sort, be it a Spacelab or a much larger free-flying laboratory such as some concepts of research-oriented space stations. Fabrication and warehousing are similar functions that, although representing larger satellites, are needed for fewer initiatives. The same trend is evident in the needs for these functions in the other worlds, with the smallest call being for Worlds #1 and #3. Though there may well be a need for "space stations" as research tools to determine the utility of man, to perform general research, and to determine his limits, the present work only addresses the needs for facilities to support the initiative system concepts. Thus, the term "space station" is not used herein, though functionally the above classes of space vehicles may be identical with some versions of such stations, and they may be called upon to perform similar functions. This is particularly true if the supporting functions require manned operations.


MISSION OPPORTUNITIES FOR ORBITAL SUPPORT FACILITIES
MISSION OPPORTUNITIES
200
100
0
1
2
3
4
5
6
WORLD NUMBER
UNIVERSAL TEST SATELLITE
ASSEMBLY AND MAINTENANCE YARD
RESEARCH LABORATORY
WAREHOUSE
FABRICATION

The technologies and techniques most in demand are large RF antenna structures and assemblies, with assembly and initialization done in space. This is true for all intermediate worlds as was the case for the previous four charts. The term "large antennas" includes monolithic structures and the concept of stationkept sub-arrays. The functions of man include assembly, orientation, functional "tweaking," initialization, and repair.

High energy lasers, high power radar, and large optics have a considerably smaller calling although it tends to be fairly constant for the inbetween worlds. The smaller number of opportunities for optics, lasers, and high power radar reflect the smaller number of initiatives in observation compared to communications, though this disparity actually reflects mainly study team limitations in time and resources rather than a priority emphasis. No such priority was intended.

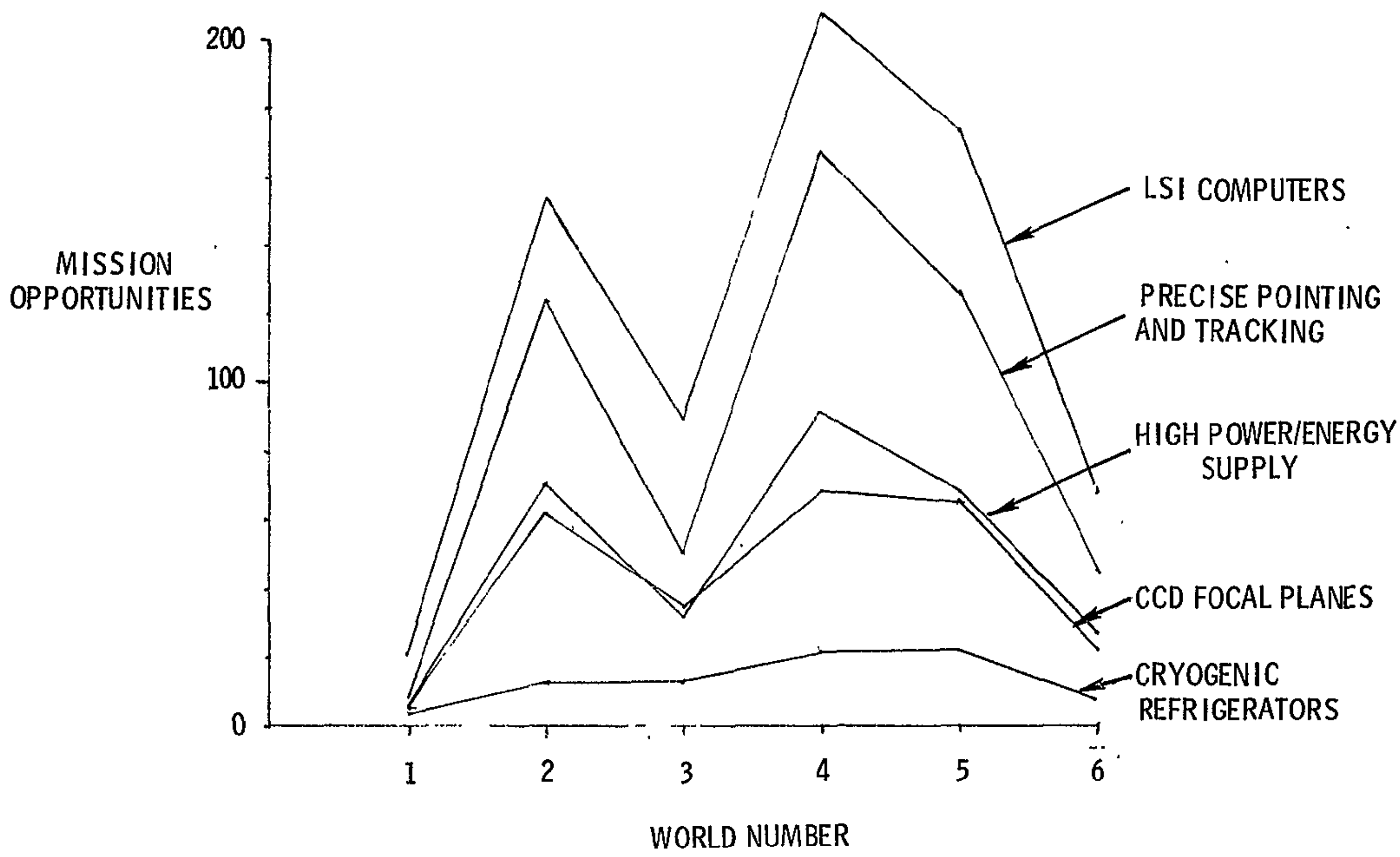
MISSION OPPORTUNITIES FOR ORBITAL TECHNIQUES AND TECHNOLOGY



This is a continuation of the subject of the previous graph in which large-scale integration of microelectronics and computers, precise pointing and tracking of optical or microwave devices, high power/energy prime and transformed sources, and charge-coupled-devices are seen to have great calling in all of the intermediate worlds, and reasonably large calling in World #6. Cryogenic refrigerators to support long-wave infrared operations in space are seen to have a small but constant demand in most of the worlds considered.

The peaking in Worlds #2 and #4 again reflects the large number of big, complex systems fielded in these worlds, with their resultant need for microelectronics, pointing of large apertures, and high power needs. Significantly, however, a minimum need exists regardless of the world condition.

MISSION OPPORTUNITIES FOR ORBITAL TECHNIQUES AND TECHNOLOGY



COMMON NEEDS FOR
NASA AND DOD

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SECTION 7

COMMON NEEDS FOR NASA AND DOD

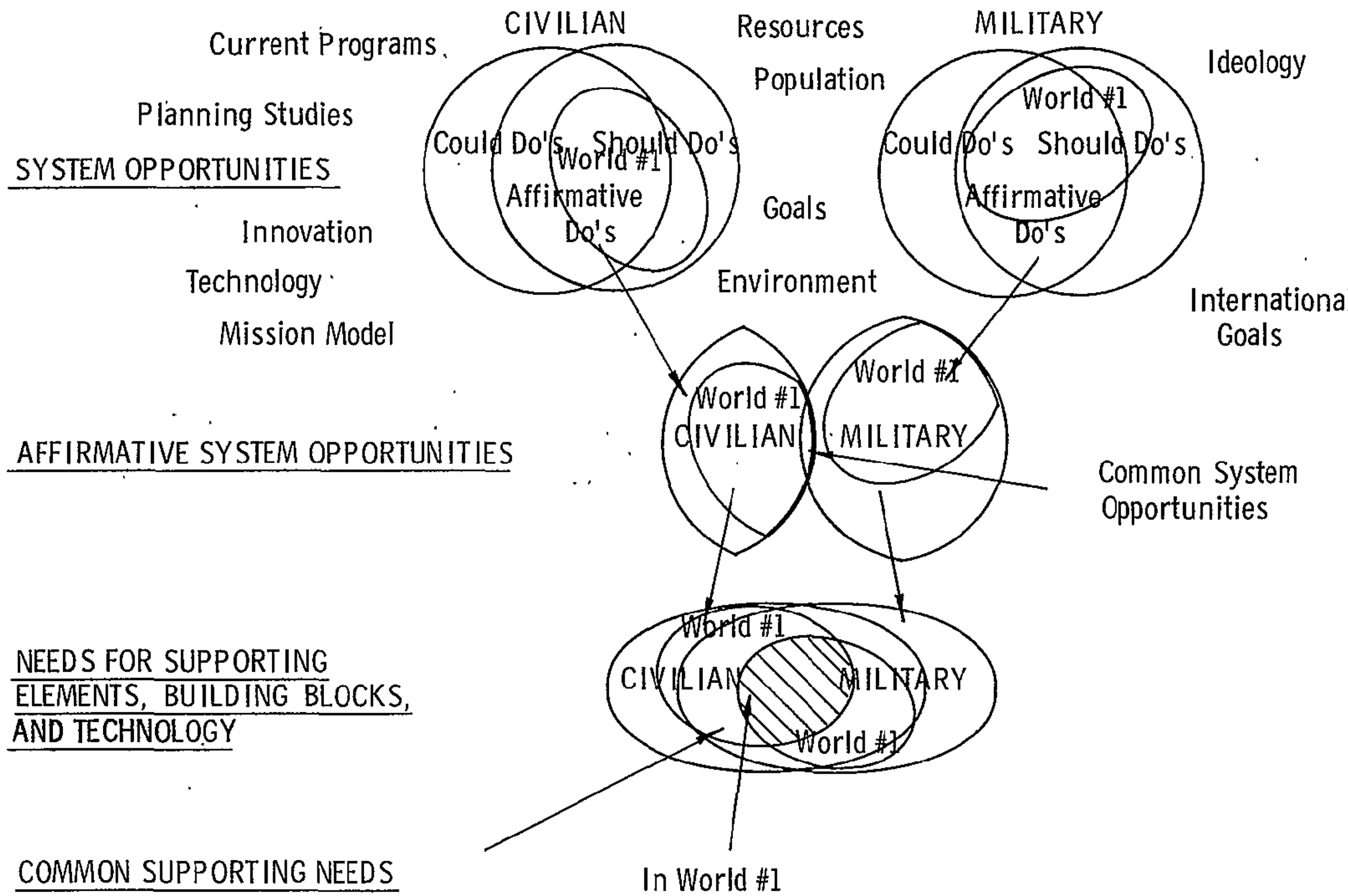
COMMON NEEDS FOR NASA AND DOD

E-2029

This section develops the definitions of NASA and DoD commonality which are used in the report and presents the data of the output of the study. Reference is made to the diagram on the facing page. The system opportunities were selected (in Volume III) for both civilian and military opportunities in the following way: one set of lists was prepared from those initiative opportunities which technology might support in the next 25 years, regardless of any accepted need for the capabilities. These are entitled the "could do's" on the facing page. Simultaneously, the functions which would be needed in the future environments are listed as "should do's" in the graph on the facing page regardless of the status of technology to support them. The intersection of the "could do's" and the "should do's" we call the "affirmative do's," which are the system opportunities that are not only feasible but are needed and called for in the worlds of the future. The affirmative system opportunities for the civilian and for the military communities were prepared independently using this process, and they generally represent separate and distinct initiative systems, although in some cases the same system could perform a military as well as a civilian function.

The primary output of this study is a common need for the supporting building blocks and technologies under various world conditions. This common need is developed from the needs of the military and civilian affirmative system opportunities. The intersection of the supporting needs is therefore shown as the common supporting needs. Particular definitions of the future world, such as indicated by the ellipses and resulting curves on the facing page, will result in a particular set of common supporting needs. There may well be sets of building blocks and technologies which will support all worlds in common (at least as defined in this work), and if such common sets exist, a powerful case could be made for their development.

COMMONALITY STUDY PROCESS



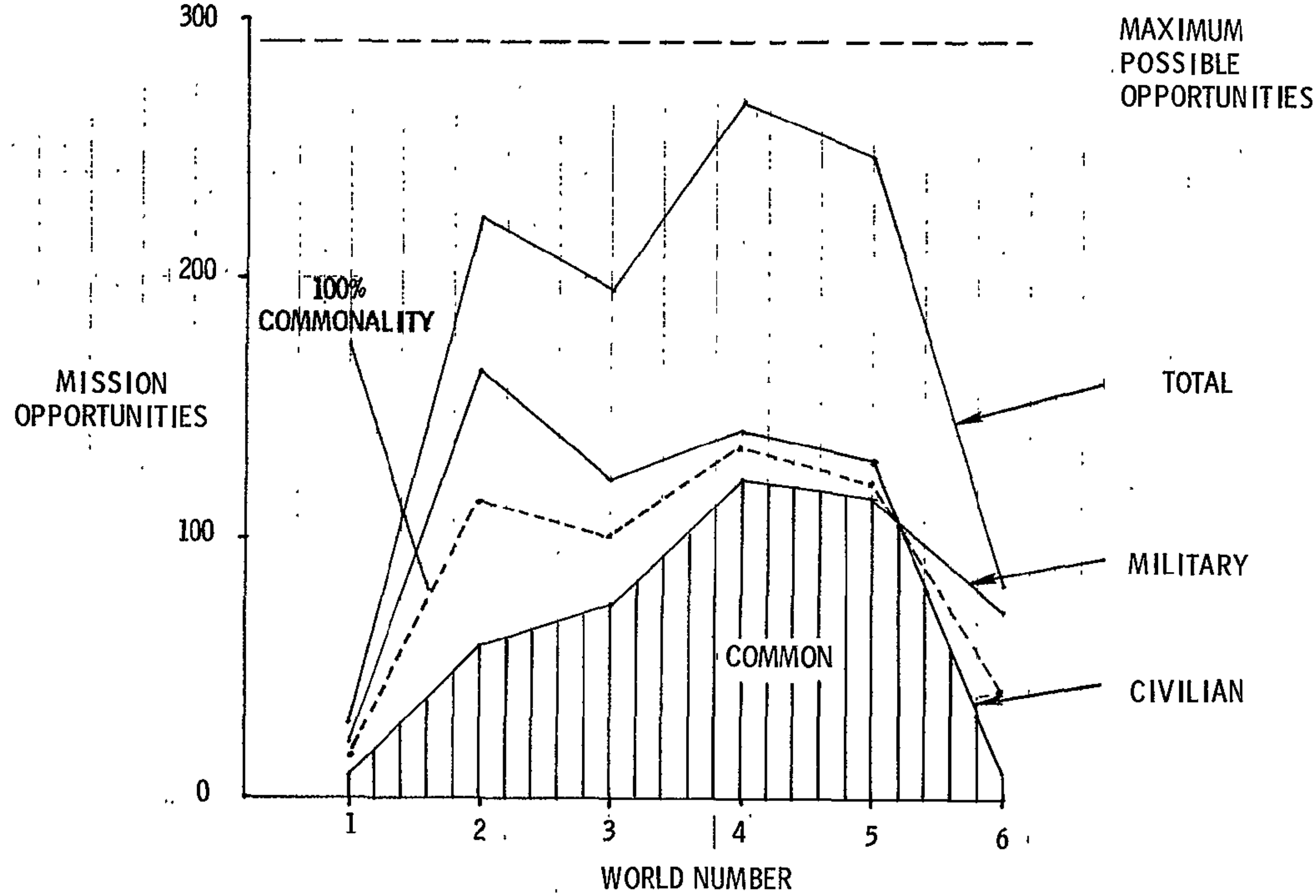
The following graphs present the common NASA/DoD supporting needs for building blocks and technologies defined for each of the alternate world scenarios considered in this study. While it is recognized that this is not the only way to derive or present commonality data, it was chosen for this study as being realizable within the time and resources available, and having a high probability of yielding meaningful results with minimum dependence on subjective assumptions.

The graph on the facing page illustrates the derivation of the commonality data for a particular example, i.e., for the space shuttle. The data on space shuttle mission opportunities as a function of world number is reproduced from page 121 and labeled the "total curve" - a summation of the military and civilian mission opportunity components. These components add up to the total curve. The maximum possible mission opportunities for the shuttle is also shown, defined as the opportunities for civilian employment of the shuttle in World #2 added to the opportunities for shuttle utilization for the military in World #4. The maximum is therefore a synthetic measure in which all mission opportunities identified are utilized, and represents a synthetic world not identified specifically. The common needs for the shuttle are defined as being the smaller of the military and civilian components. By way of example, for World #3 there are 73 mission opportunities for military application of the shuttle and 142 opportunities for civilian application. Clearly a common utilization of the shuttle exists for 73 mission applications. Therefore, that area lying underneath the lower of the military and civilian curves is by definition the number of common mission opportunities for the space shuttle, and is to be measured against the 100 percent commonality curve, defined as one half of the total opportunities. (If the military and civilian opportunities are equal, the same number supports both.

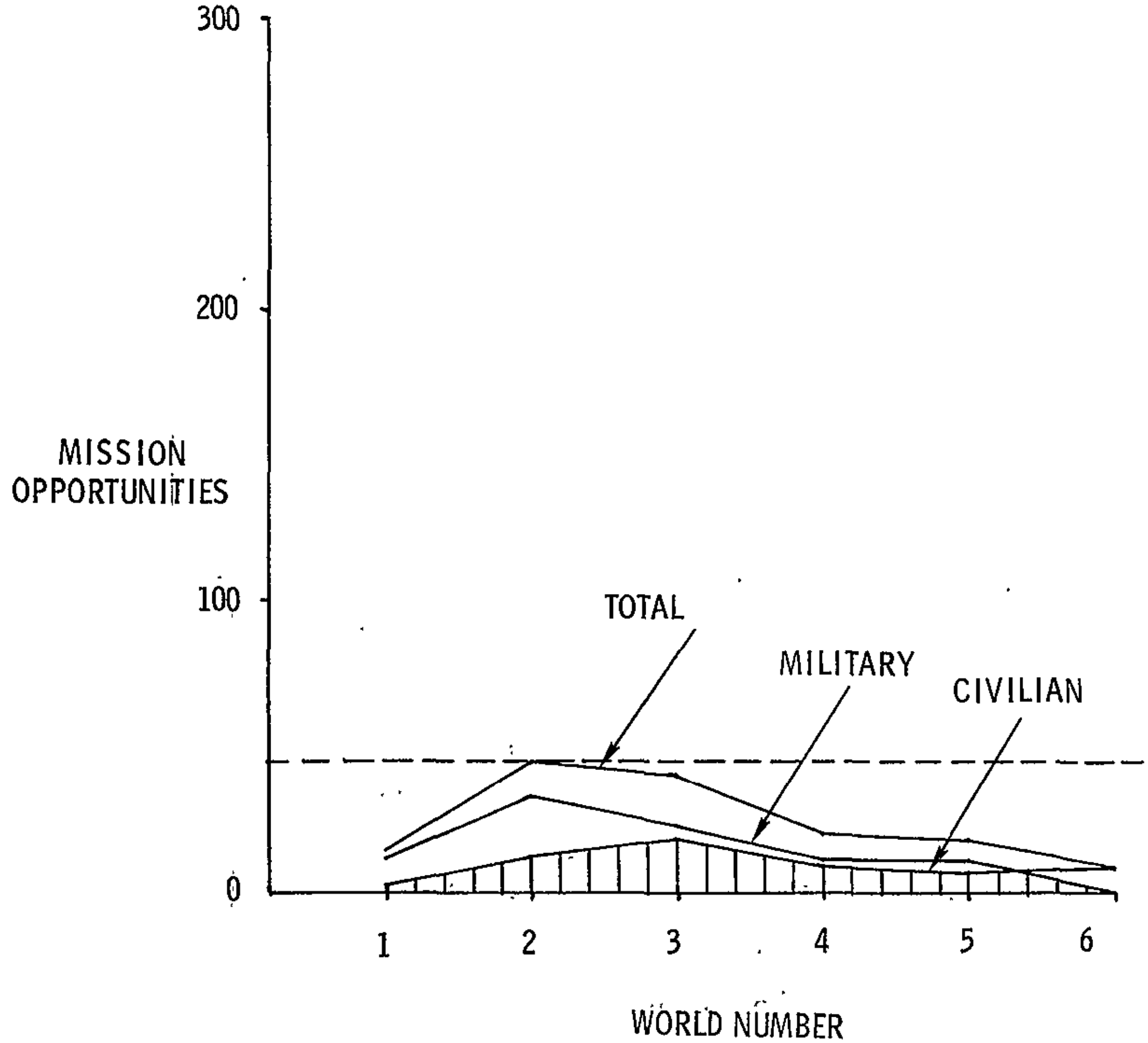
Analyzing the facing page, we find that the common needs for the space shuttle peak in Worlds #4 and #5, approaching 100 percent, and drop off on both extremes of worlds to a somewhat smaller number. The commonality still exceeds 25 percent, however, for all worlds including the catastrophic World #6. Thus, there are common requirements or

mission opportunities for the space shuttle regardless of the exact nature of the future. For all the more reasonable or moderate views of the future represented by Worlds #2 through #5, the commonality exceeds 50 percent. The statement can therefore be made that the shuttle is a booster having very high common use between the NASA and the DoD in most views of the future examined in this study. Similar mission opportunities for each of the items in the building block and technology categories are shown in the next 28 graphs, and illustrate the common needs for each building block and technology for each of the world numbers considered in this study.

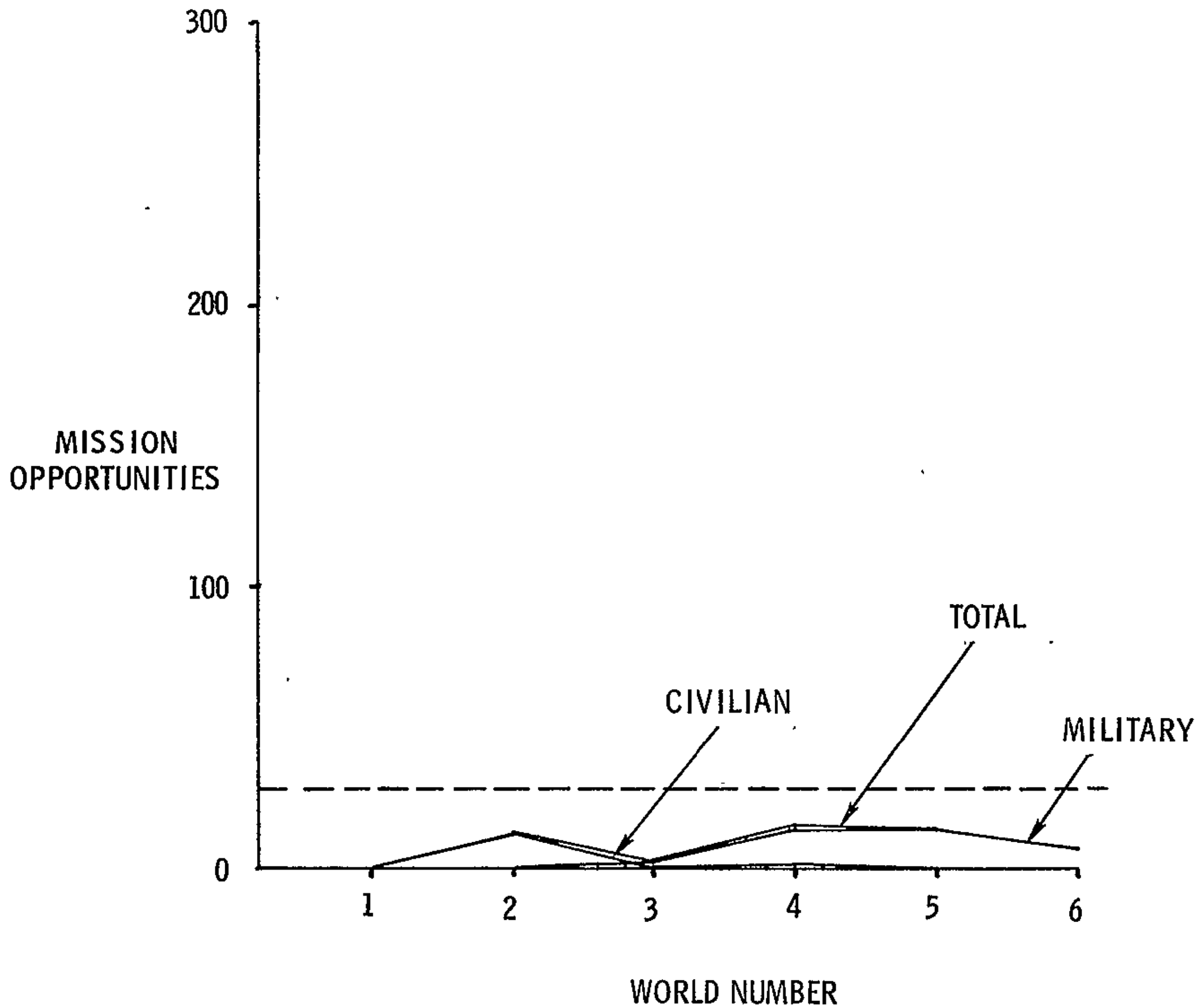
MISSION OPPORTUNITIES FOR THE SPACE SHUTTLE



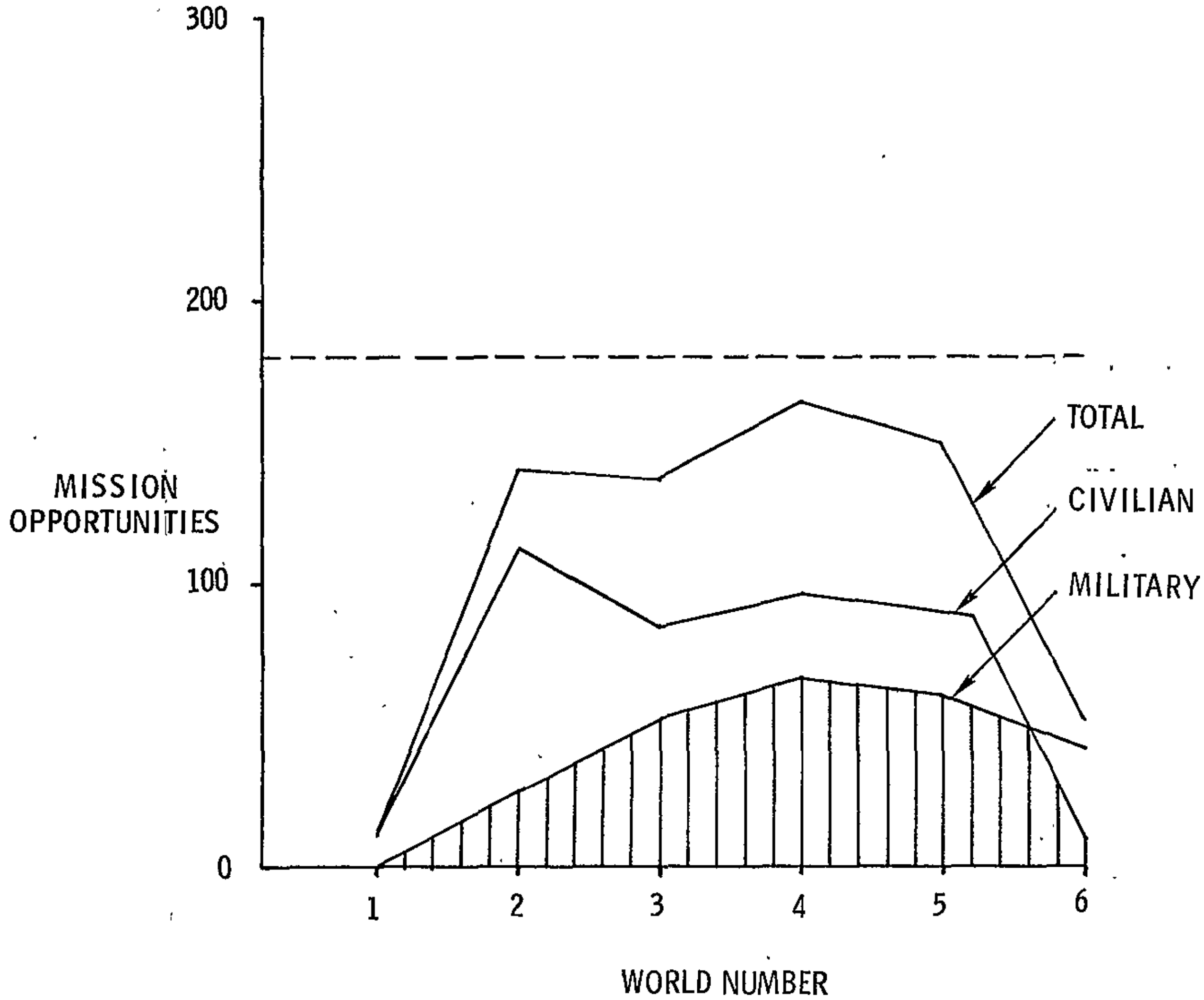
MISSION OPPORTUNITIES FOR THE EXPENDABLE BOOSTERS



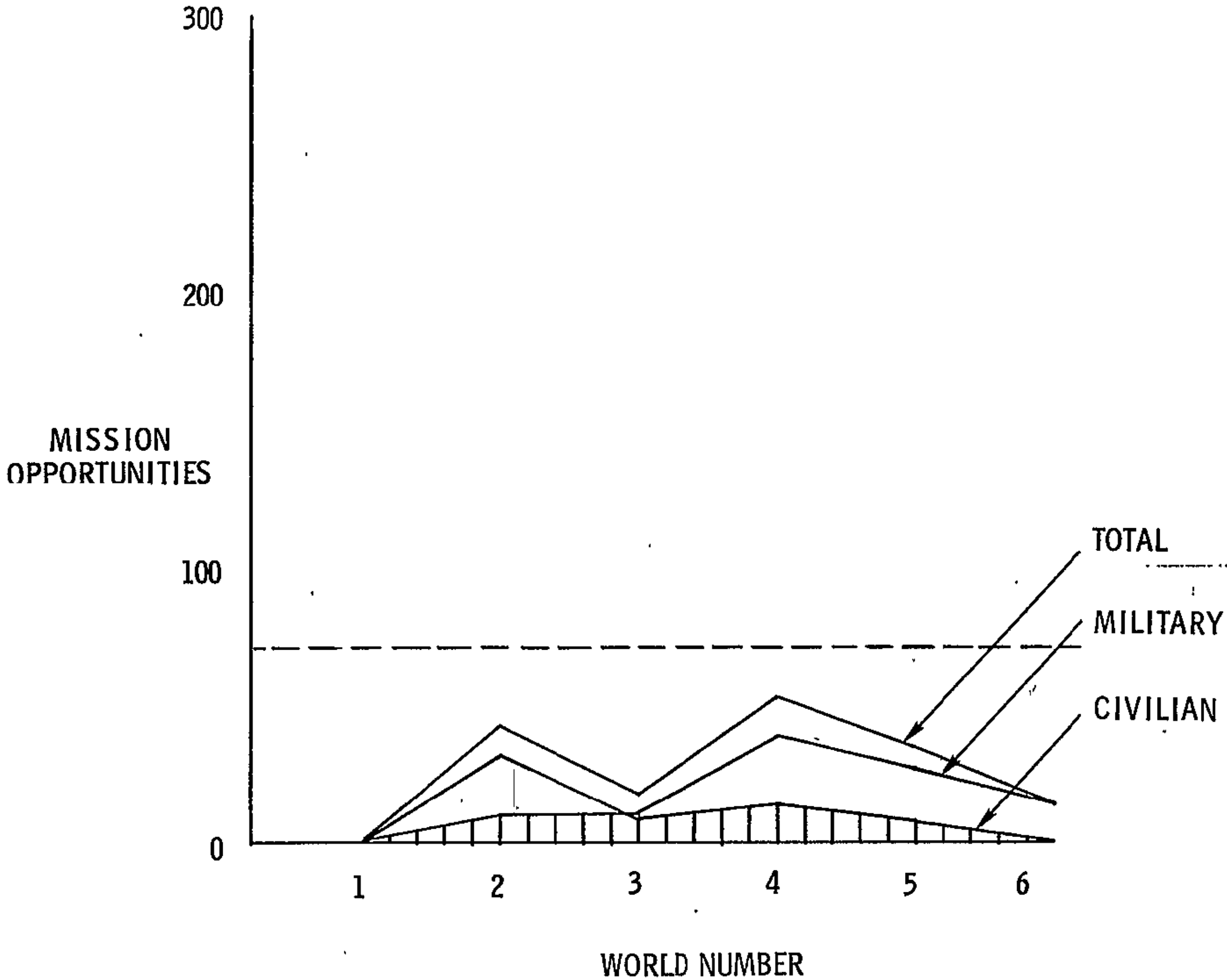
MISSION OPPORTUNITIES FOR THE LARGE LAUNCH VEHICLE



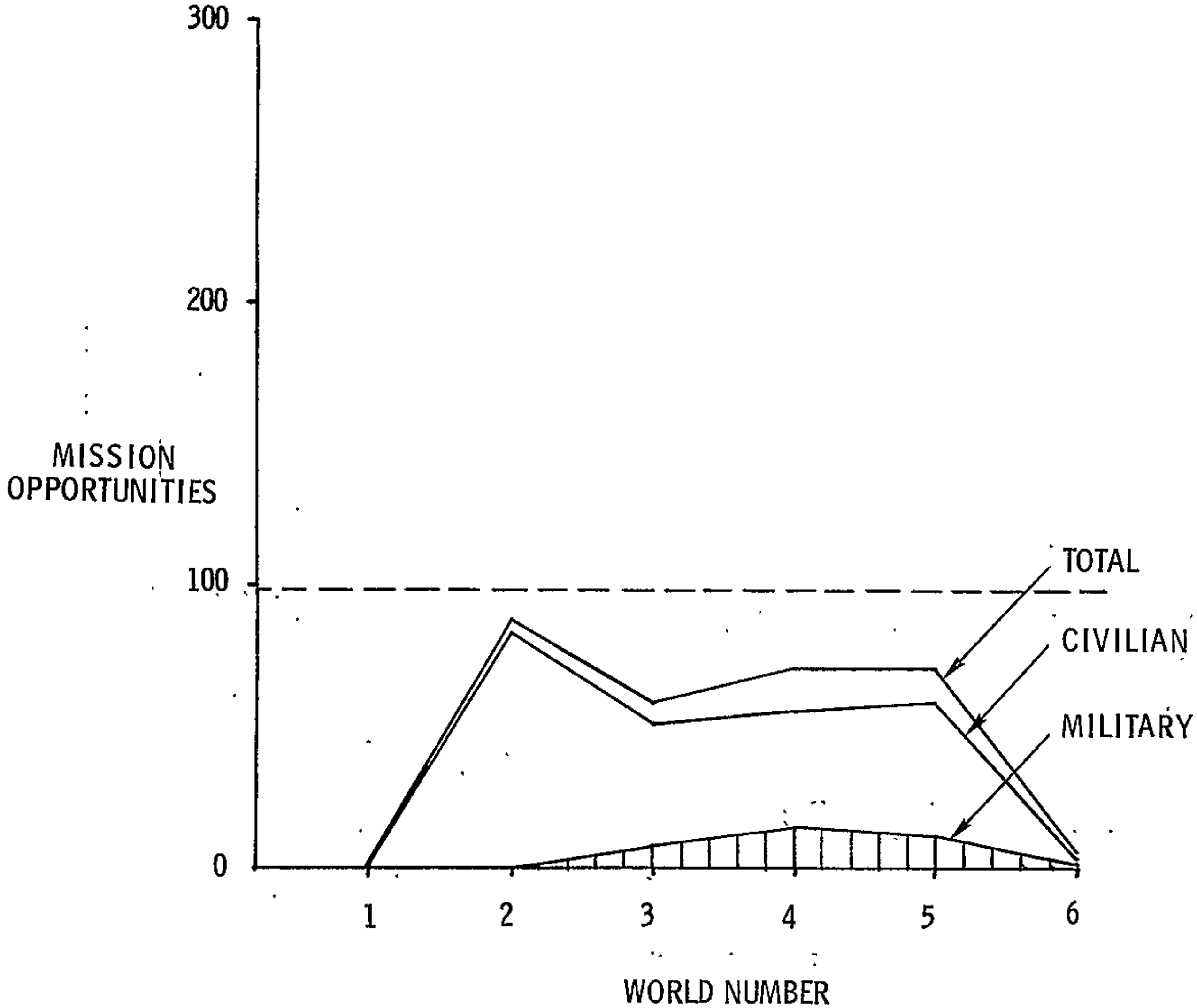
MISSION OPPORTUNITIES FOR THE TUG



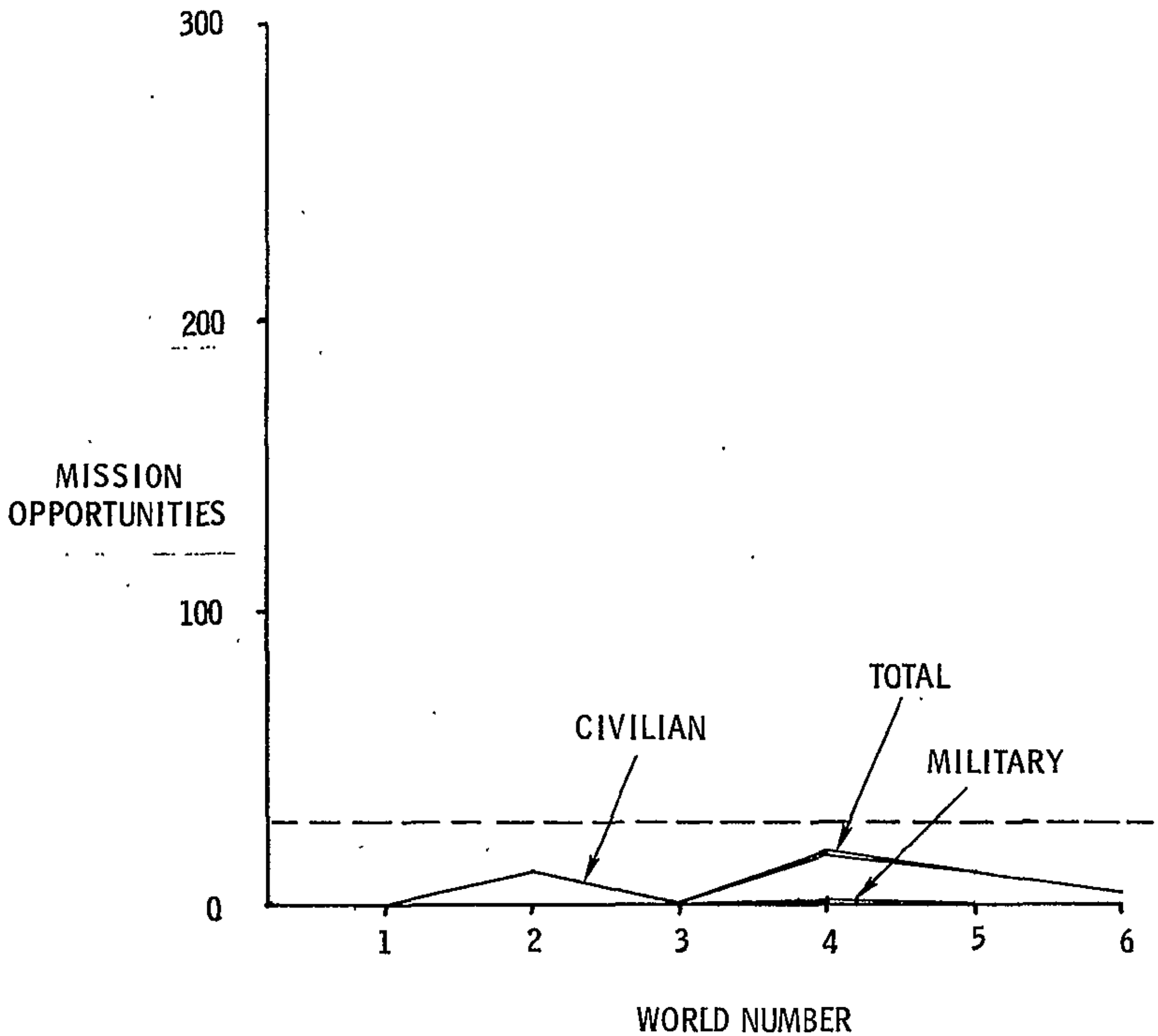
MISSION OPPORTUNITIES FOR THE LARGE TUG



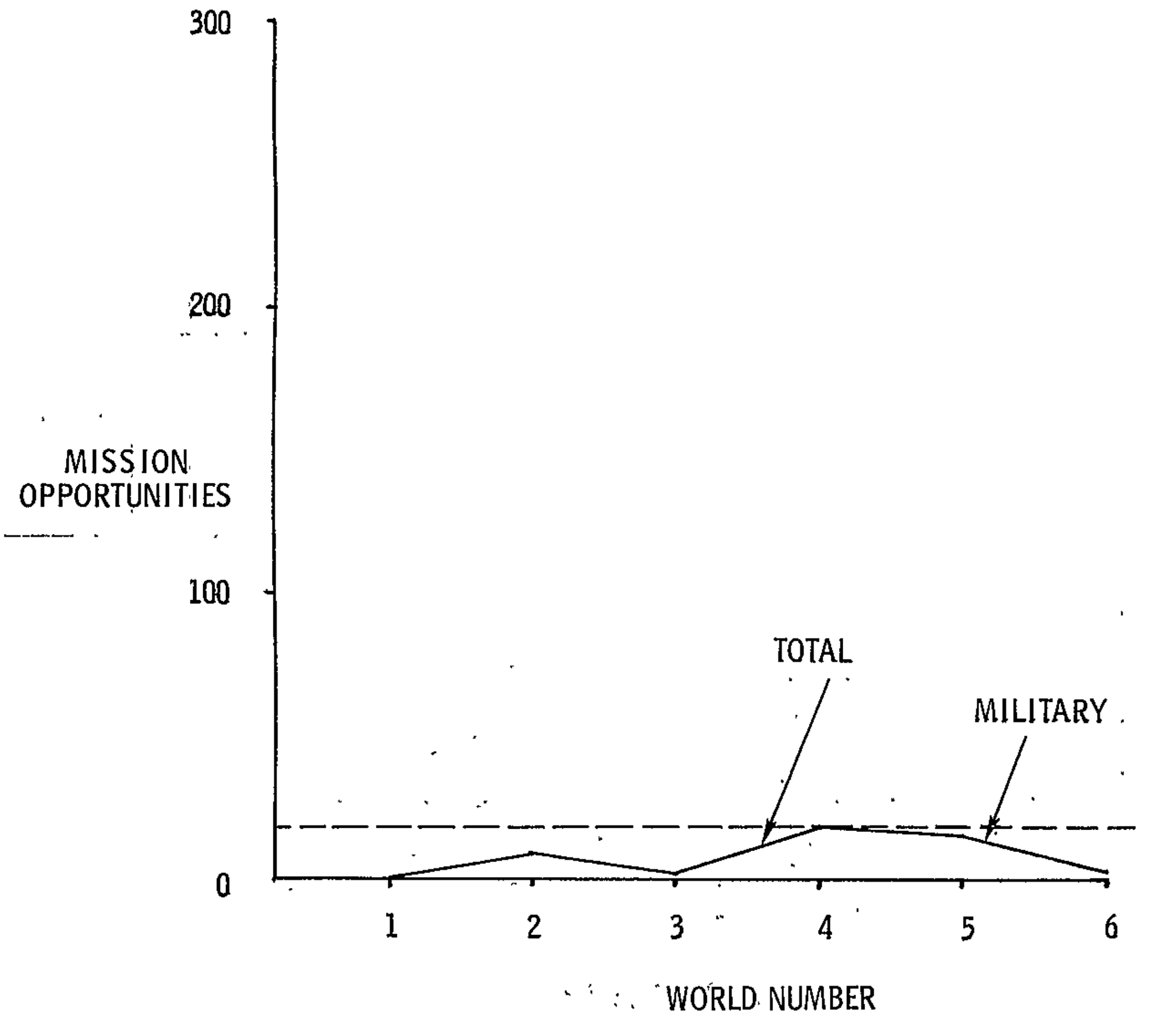
MISSION OPPORTUNITIES FOR THE SEPS



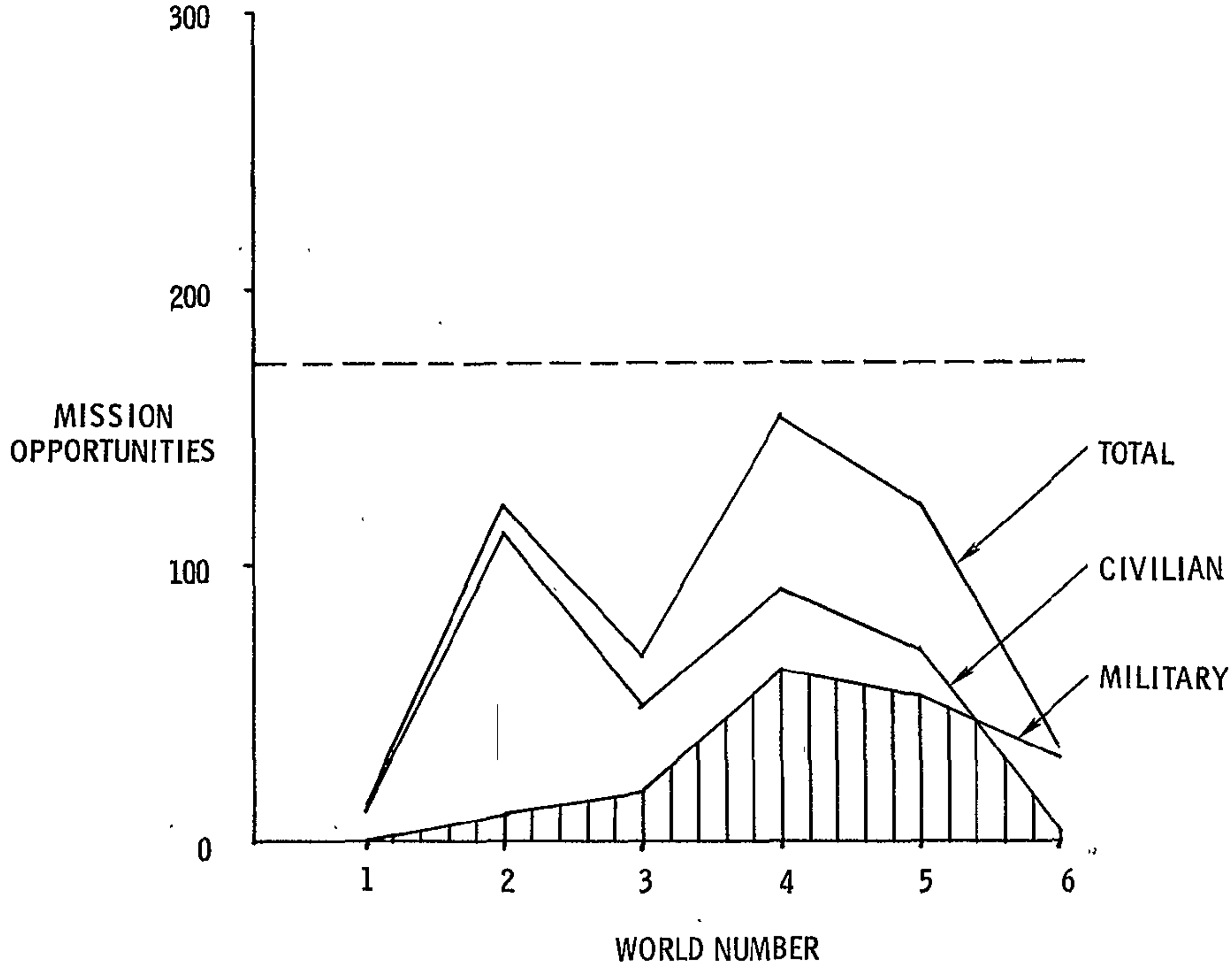
MISSION OPPORTUNITIES FOR THE LARGE SEPS



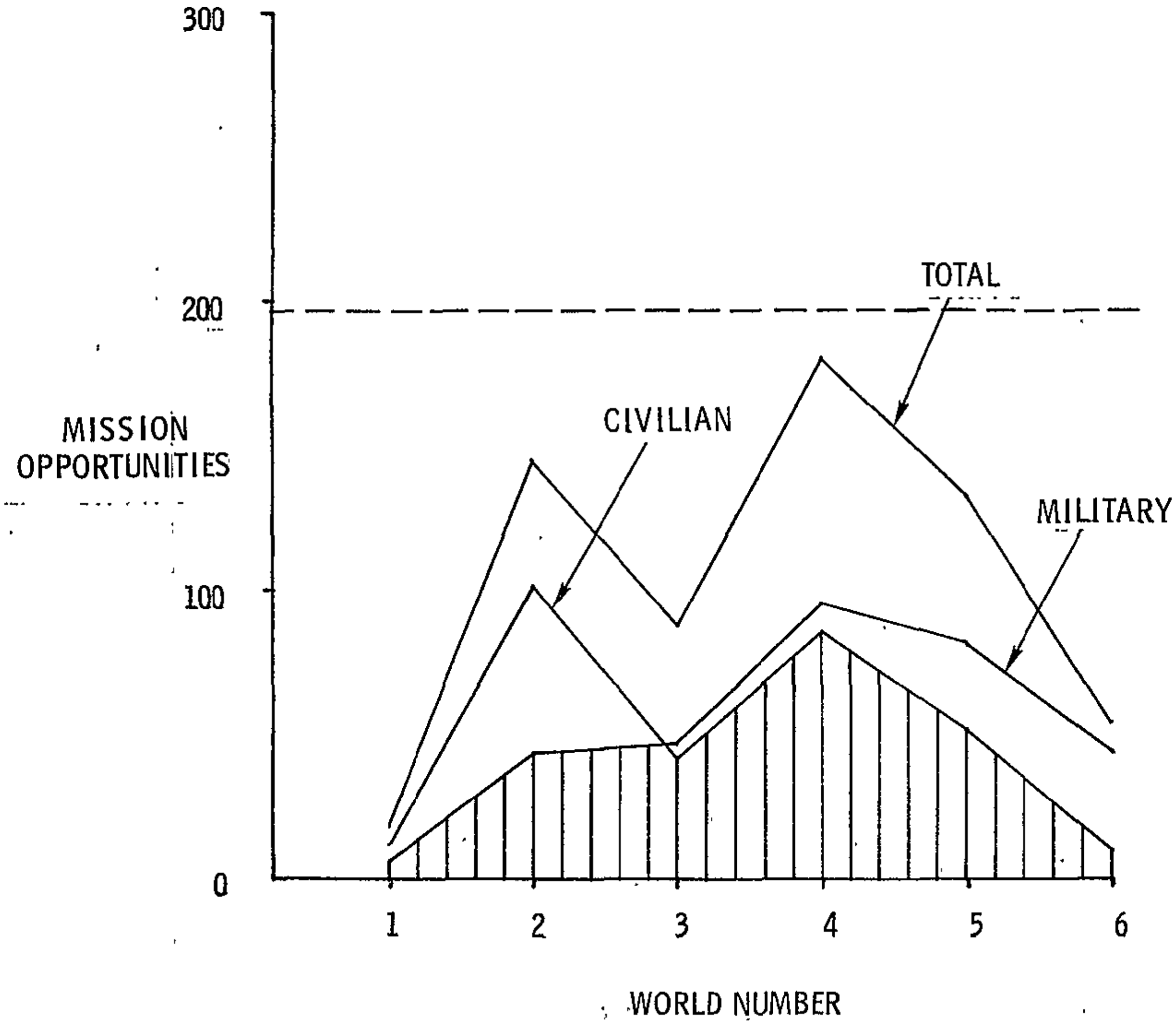
MISSION OPPORTUNITIES FOR THE NUCLEAR STAGE



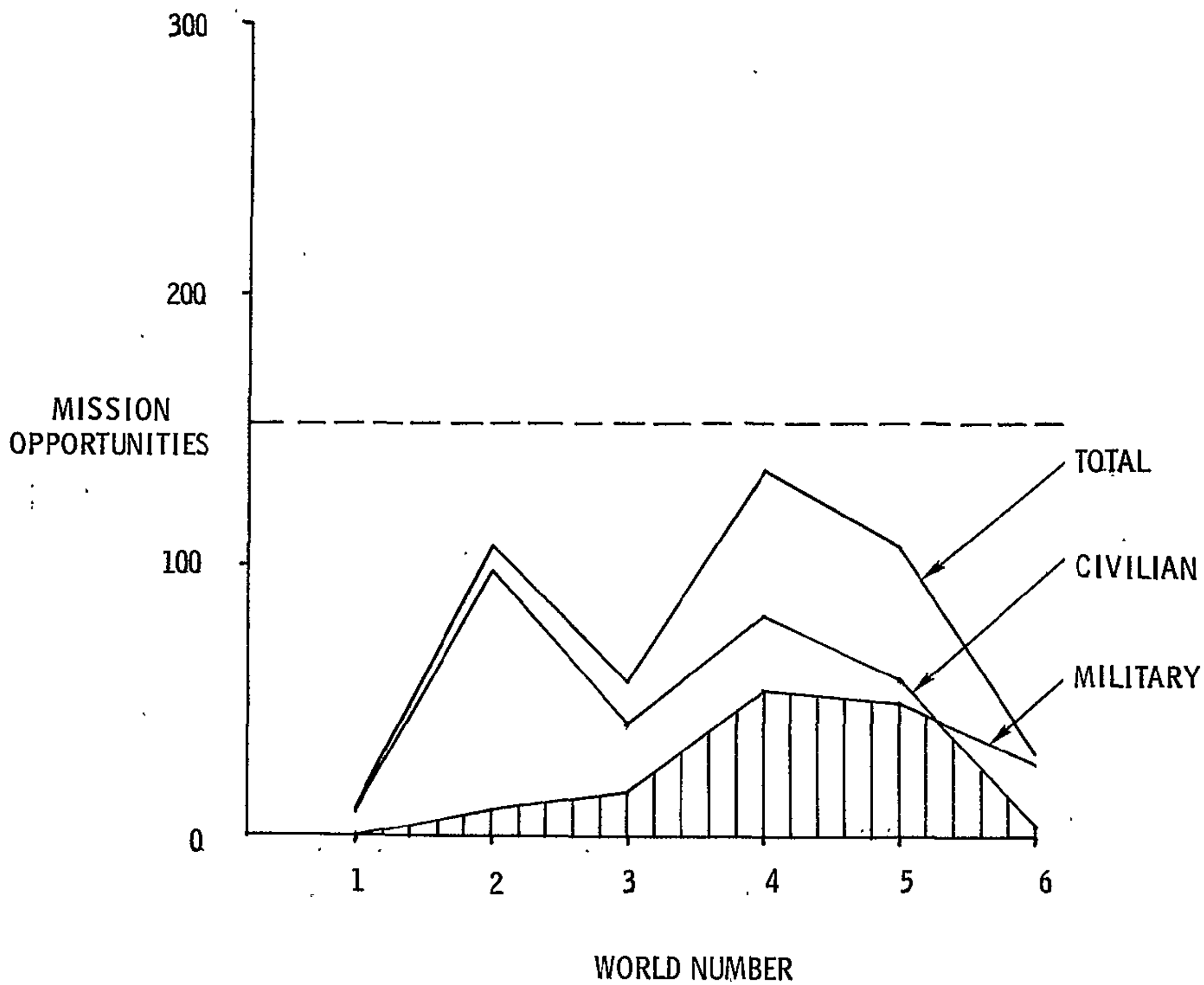
MISSION OPPORTUNITIES FOR THE SHUTTLE-ATTACHED MANIPULATOR



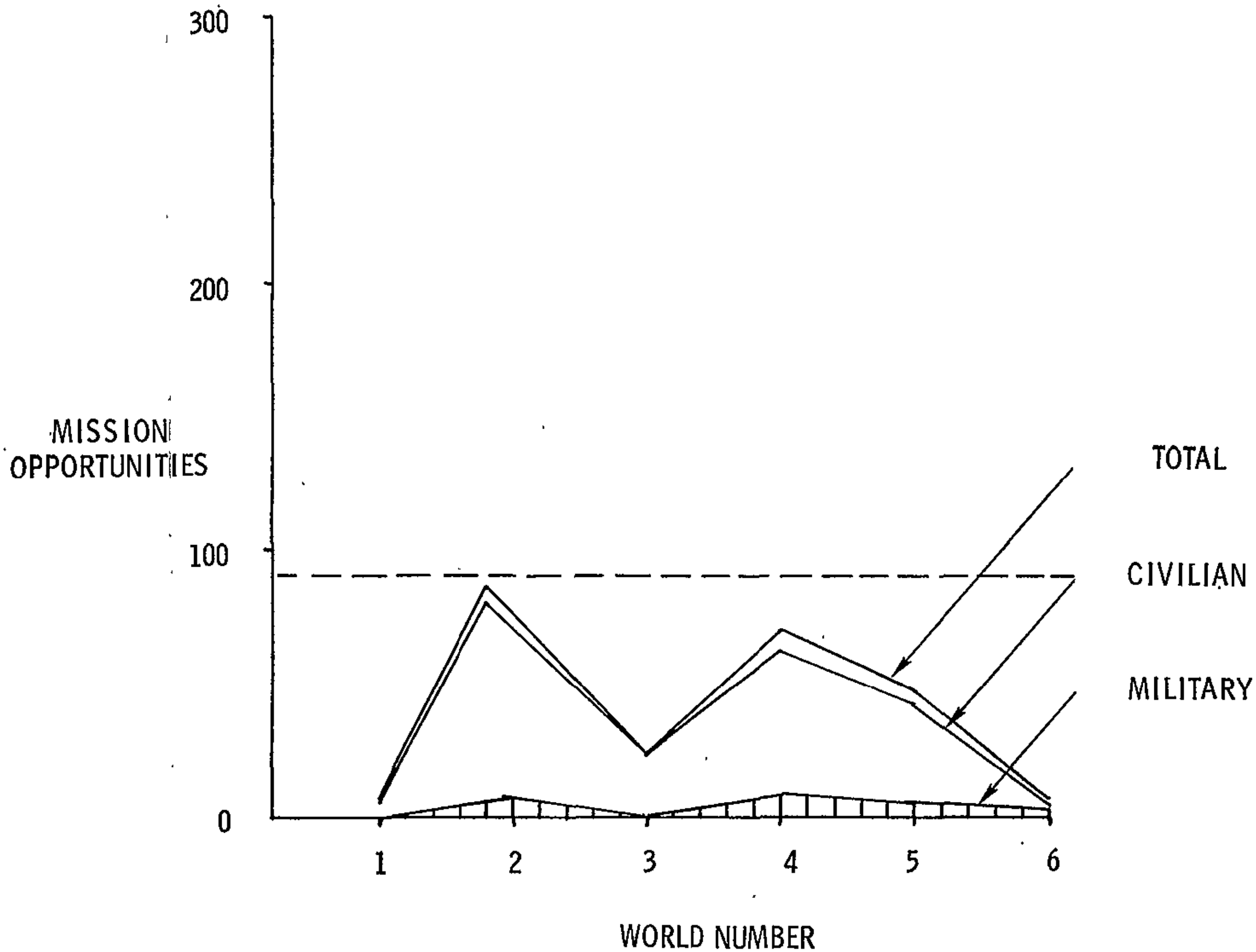
MISSION OPPORTUNITIES FOR THE AUTOMATED SERVICING UNIT



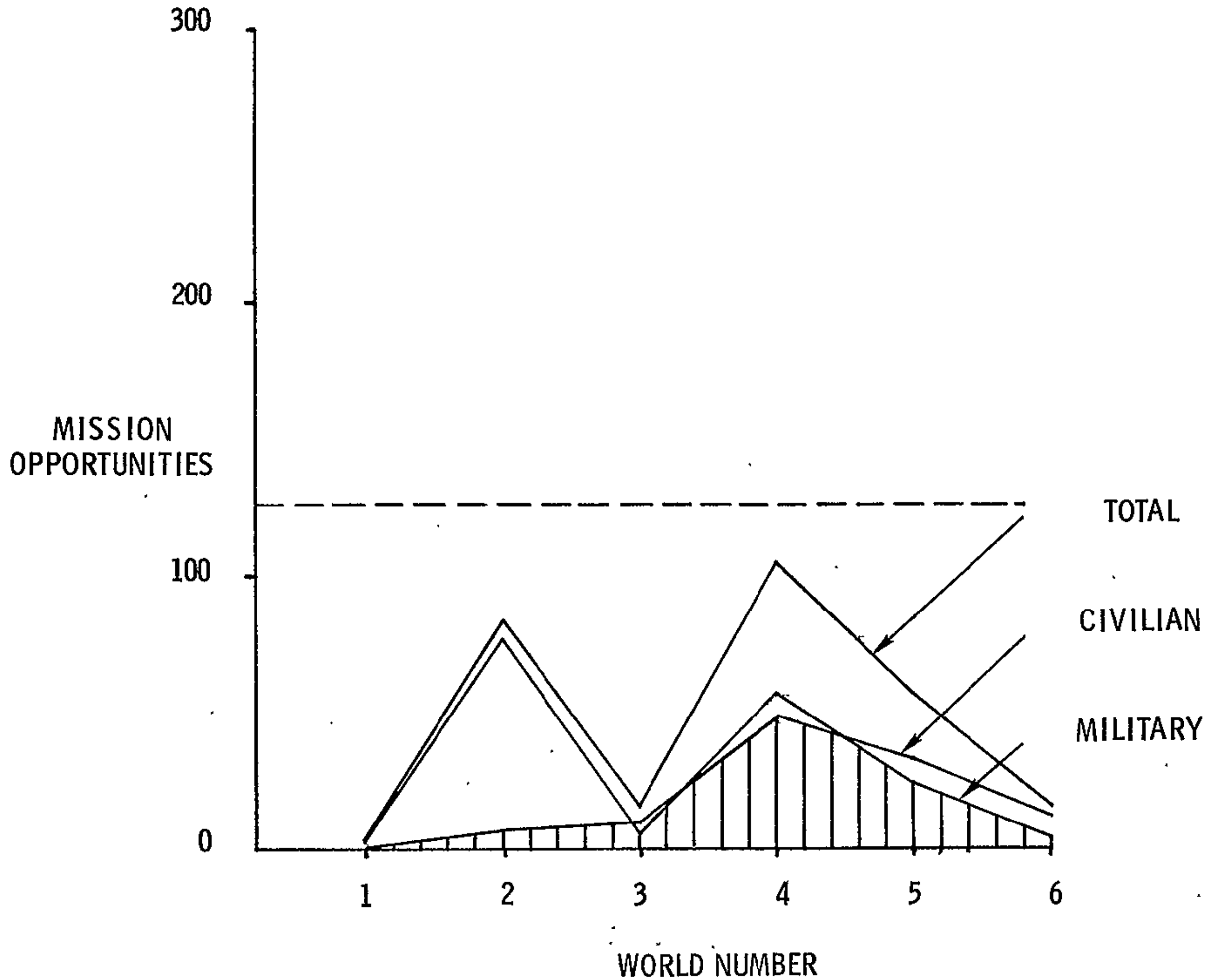
MISSION OPPORTUNITIES FOR THE MANNED SERVICING UNIT



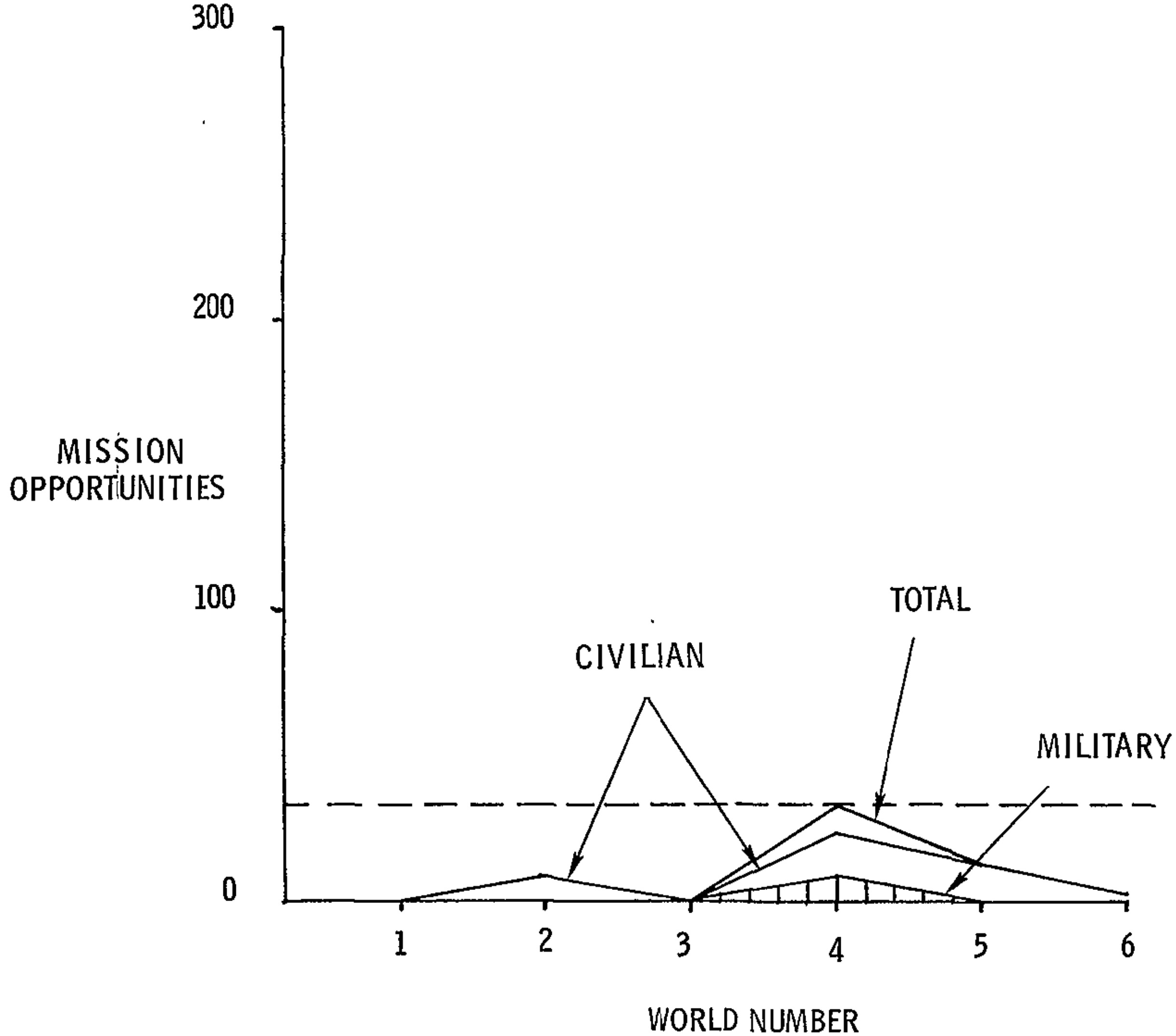
MISSION OPPORTUNITIES FOR THE FREE FLYING TELEOPERATOR



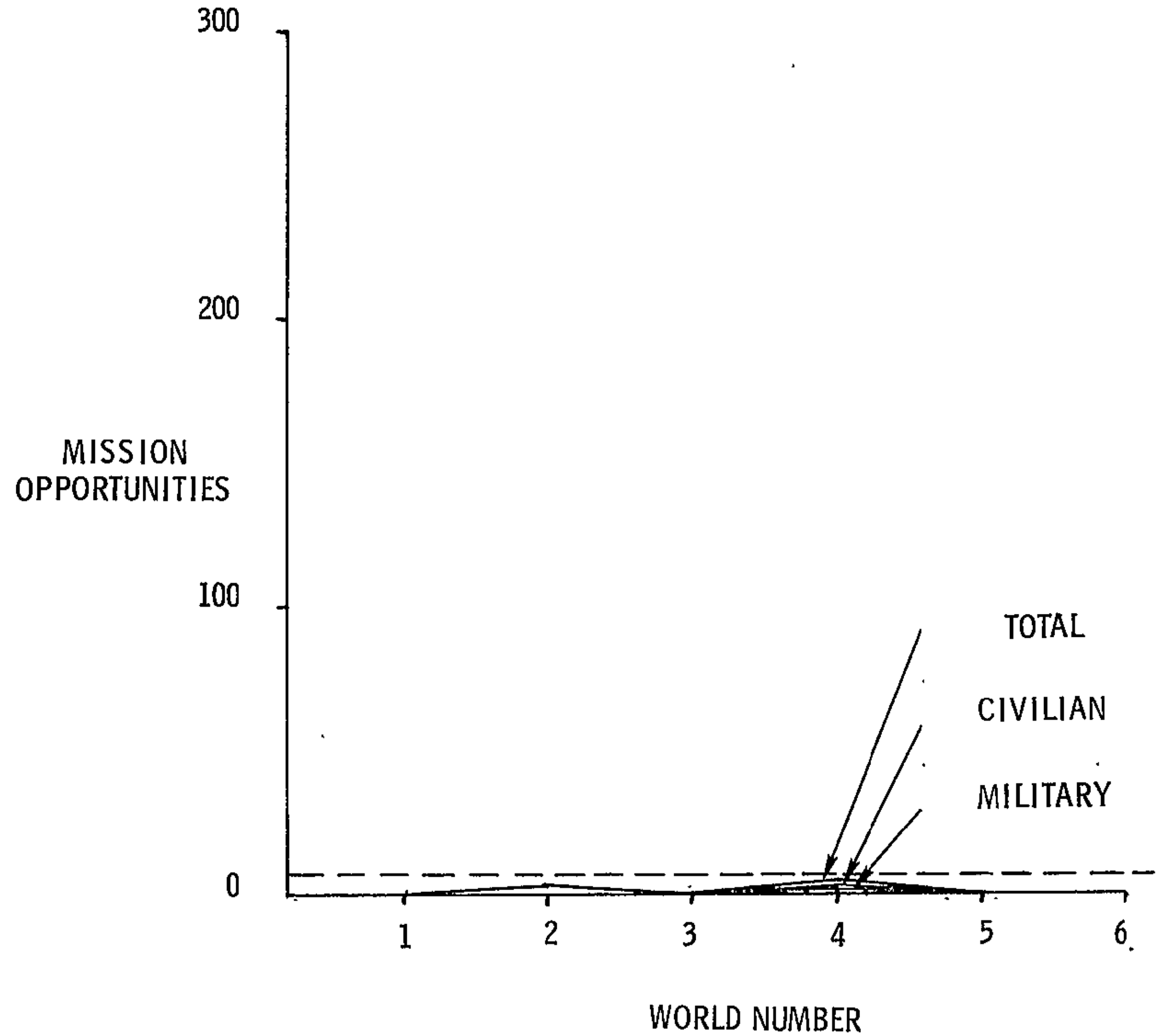
MISSION OPPORTUNITIES FOR THE ORBITAL ASSEMBLY AND MAINTENANCE FACILITY

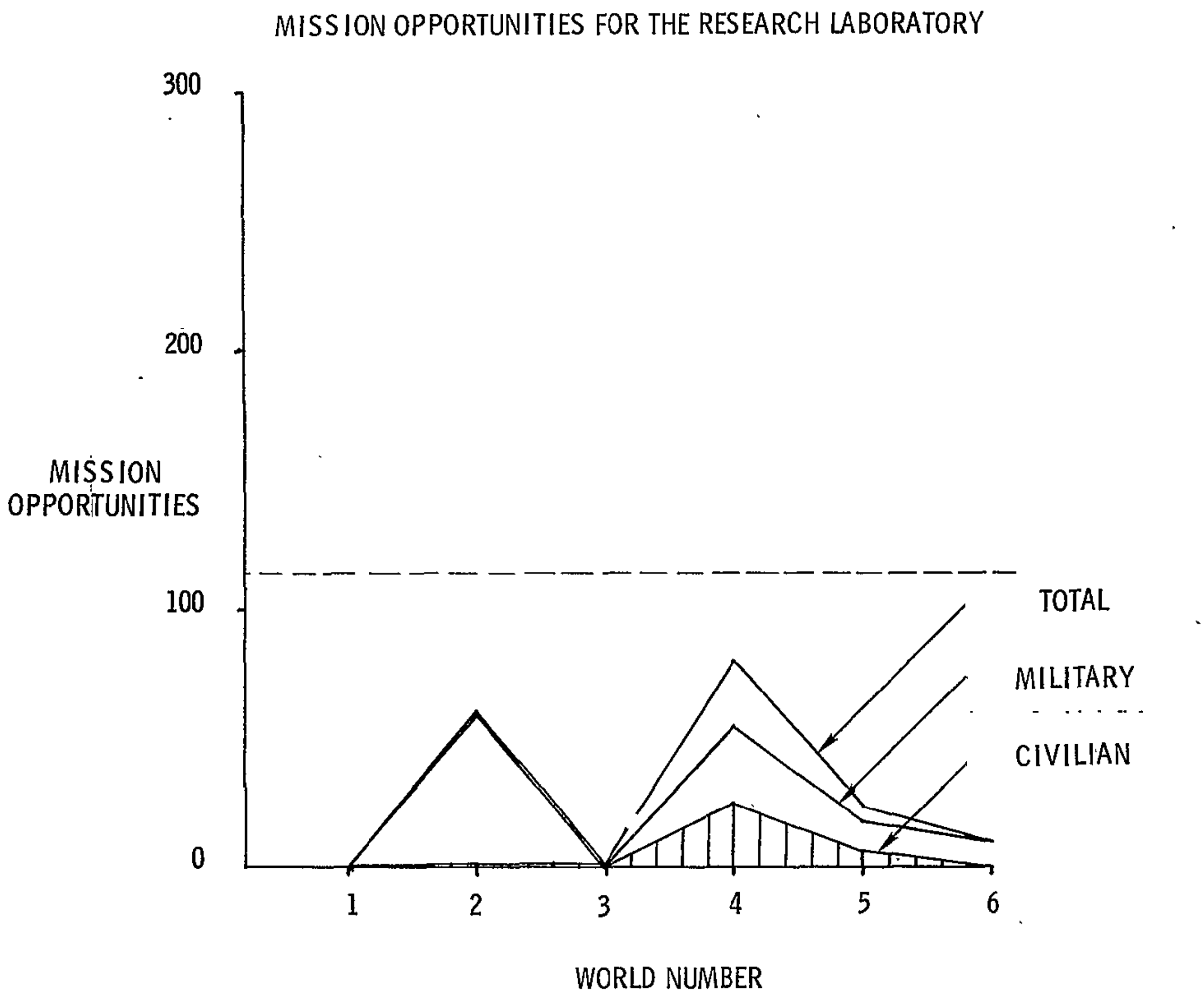


MISSION OPPORTUNITIES FOR THE ORBITAL WAREHOUSE

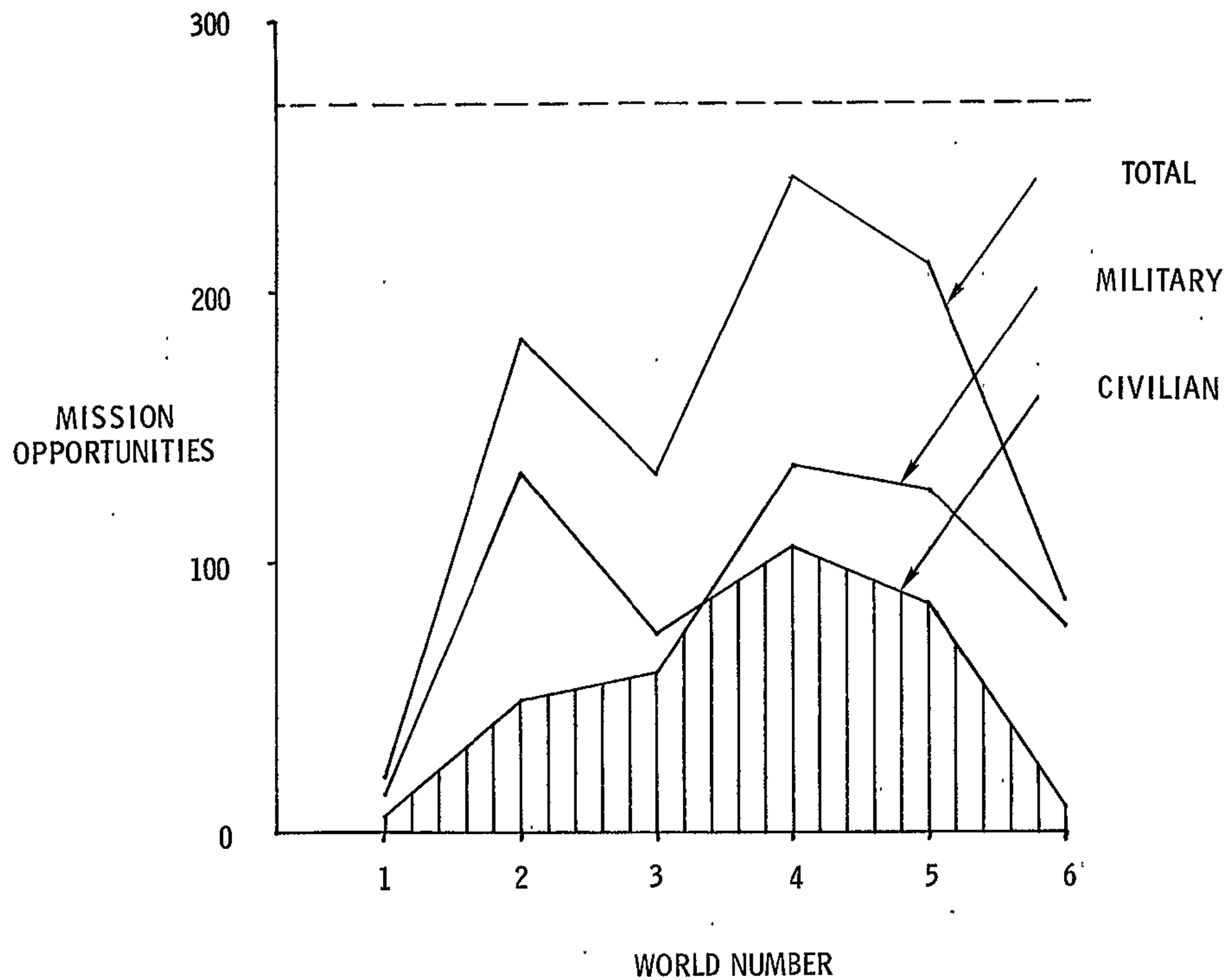


MISSION OPPORTUNITIES FOR THE ORBITAL FABRICATION FACILITY

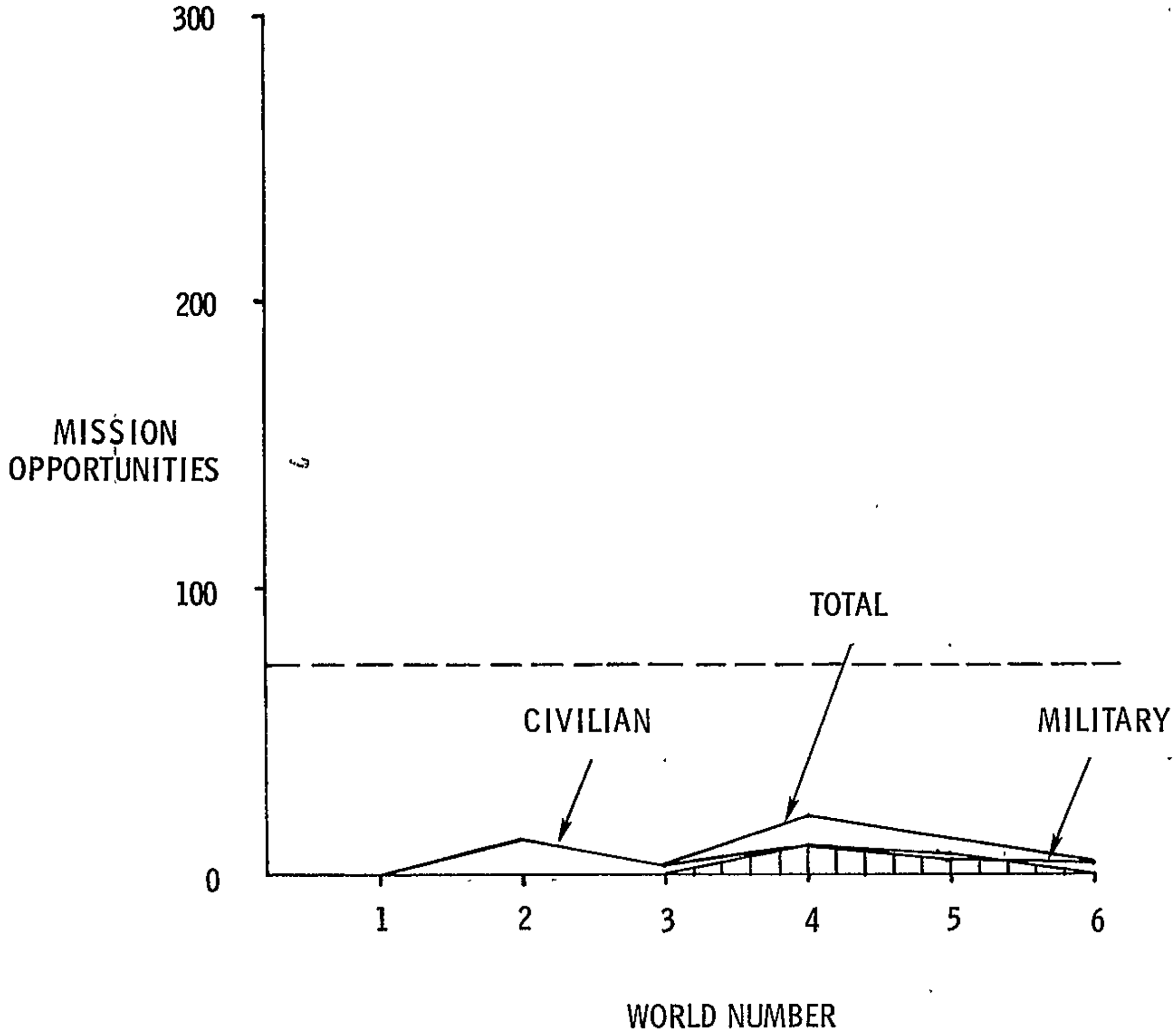



MISSION OPPORTUNITIES FOR THE RESEARCH LABORATORY
300
200
MISSION OPPORTUNITIES
100
0
TOTAL
MILITARY
CIVILIAN
1
2
3
4
5
6
WORLD NUMBER

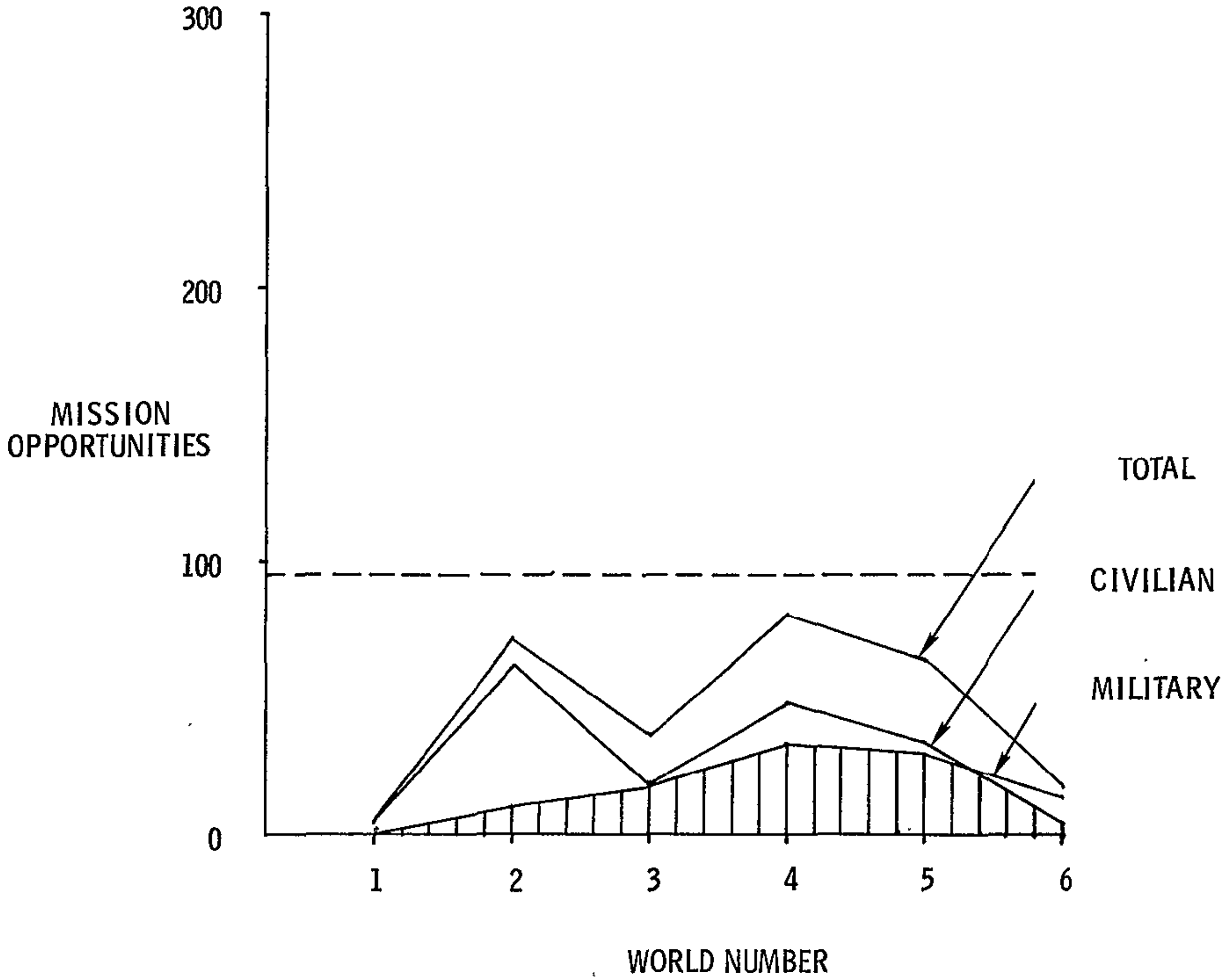
MISSION OPPORTUNITIES FOR THE UNIVERSAL TEST SATELLITE



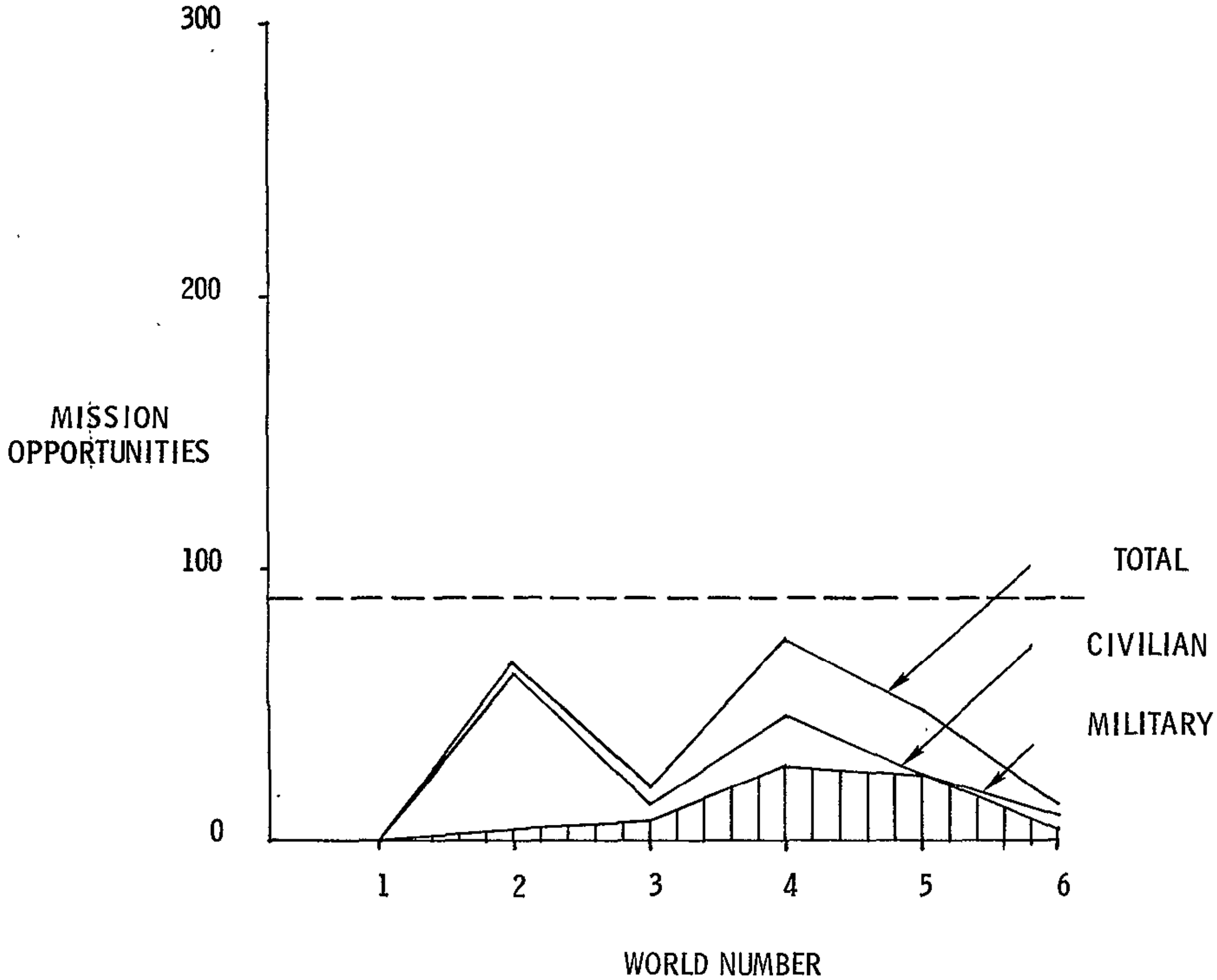
MISSION OPPORTUNITIES FOR THE LARGE OPTICS AND MIRRORS



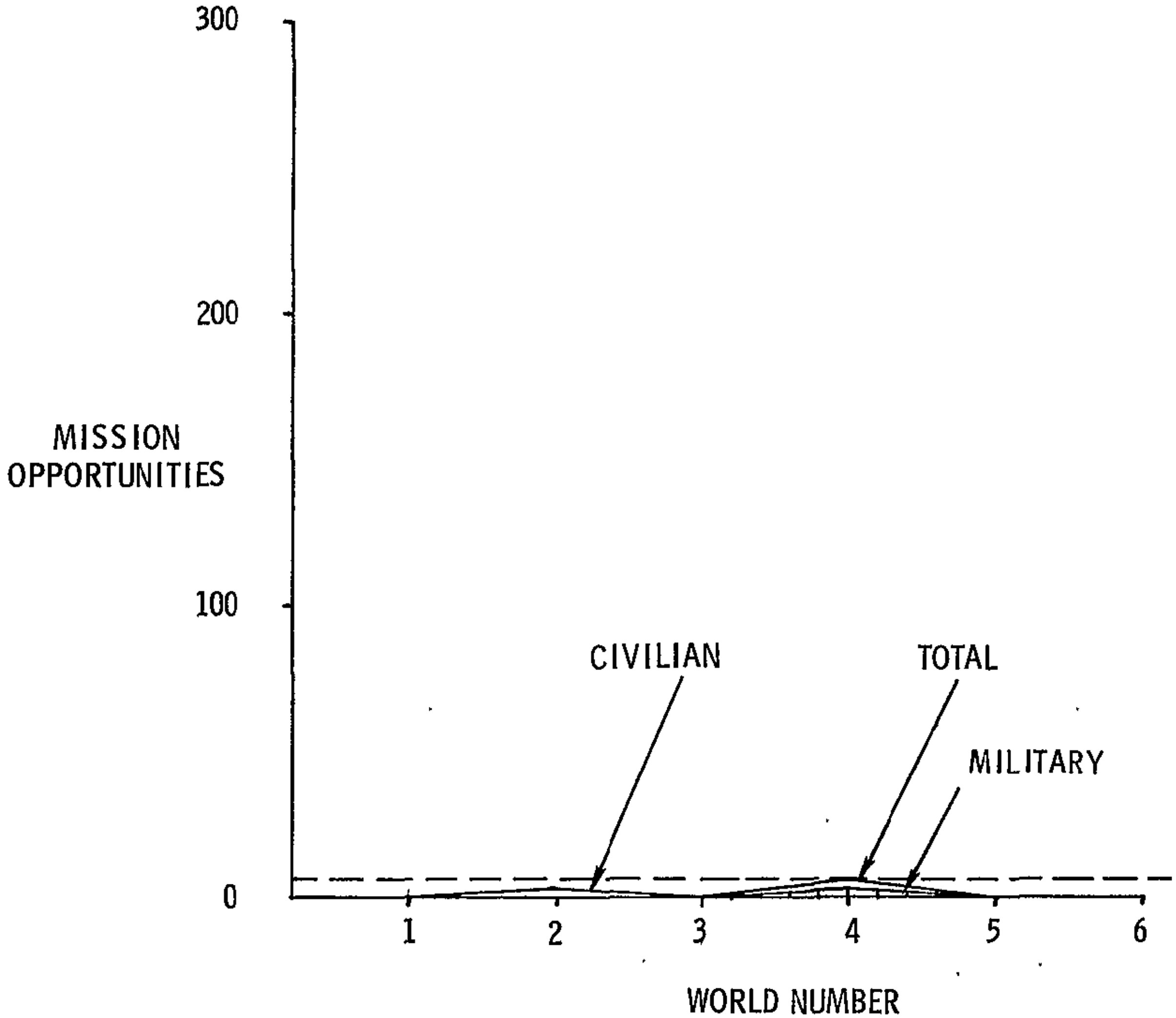
MISSION OPPORTUNITIES FOR THE LARGE RF/MICROWAVE ANTENNAS

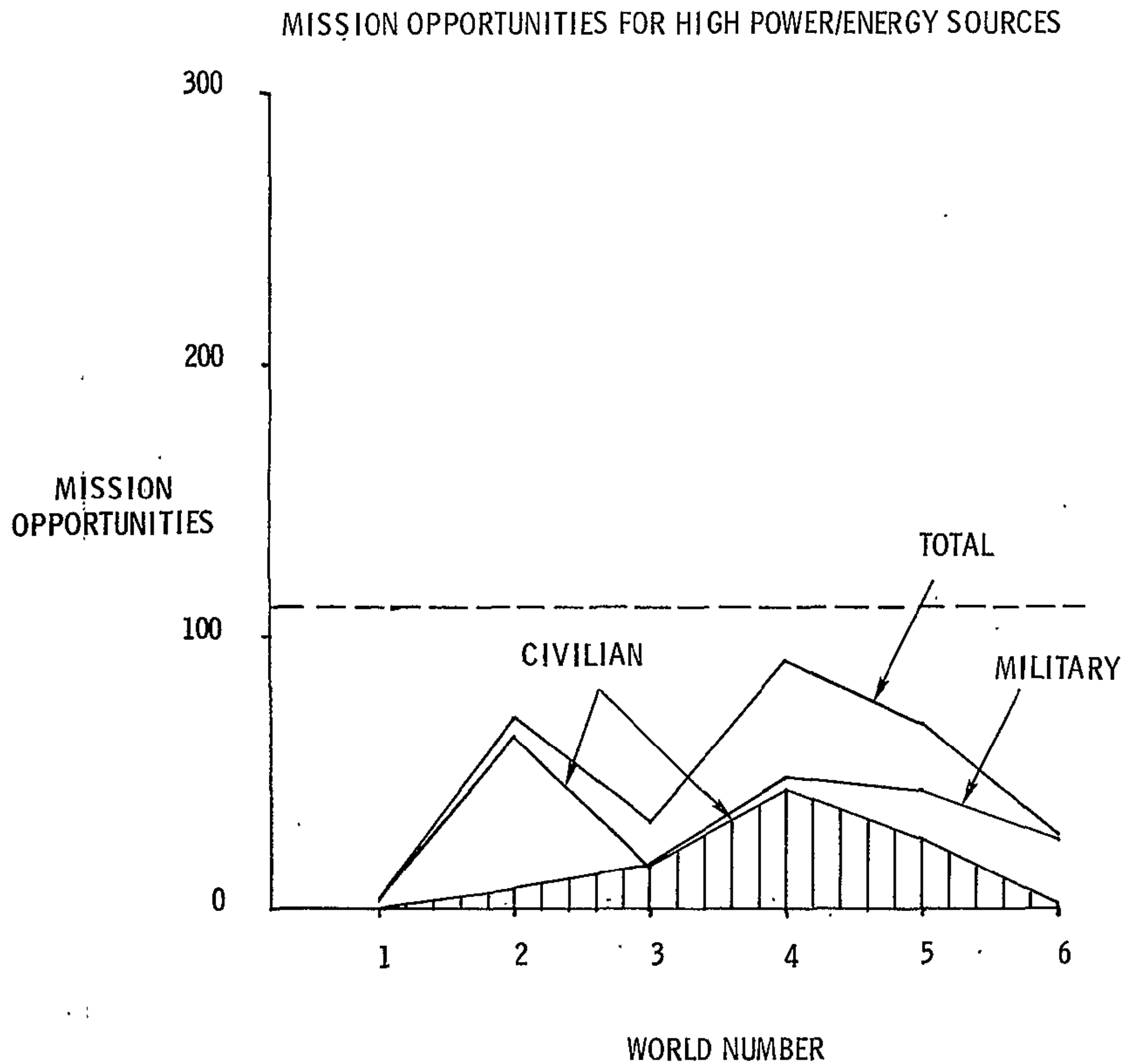


MISSION OPPORTUNITIES FOR THE MANNED ORBITAL ASSEMBLY



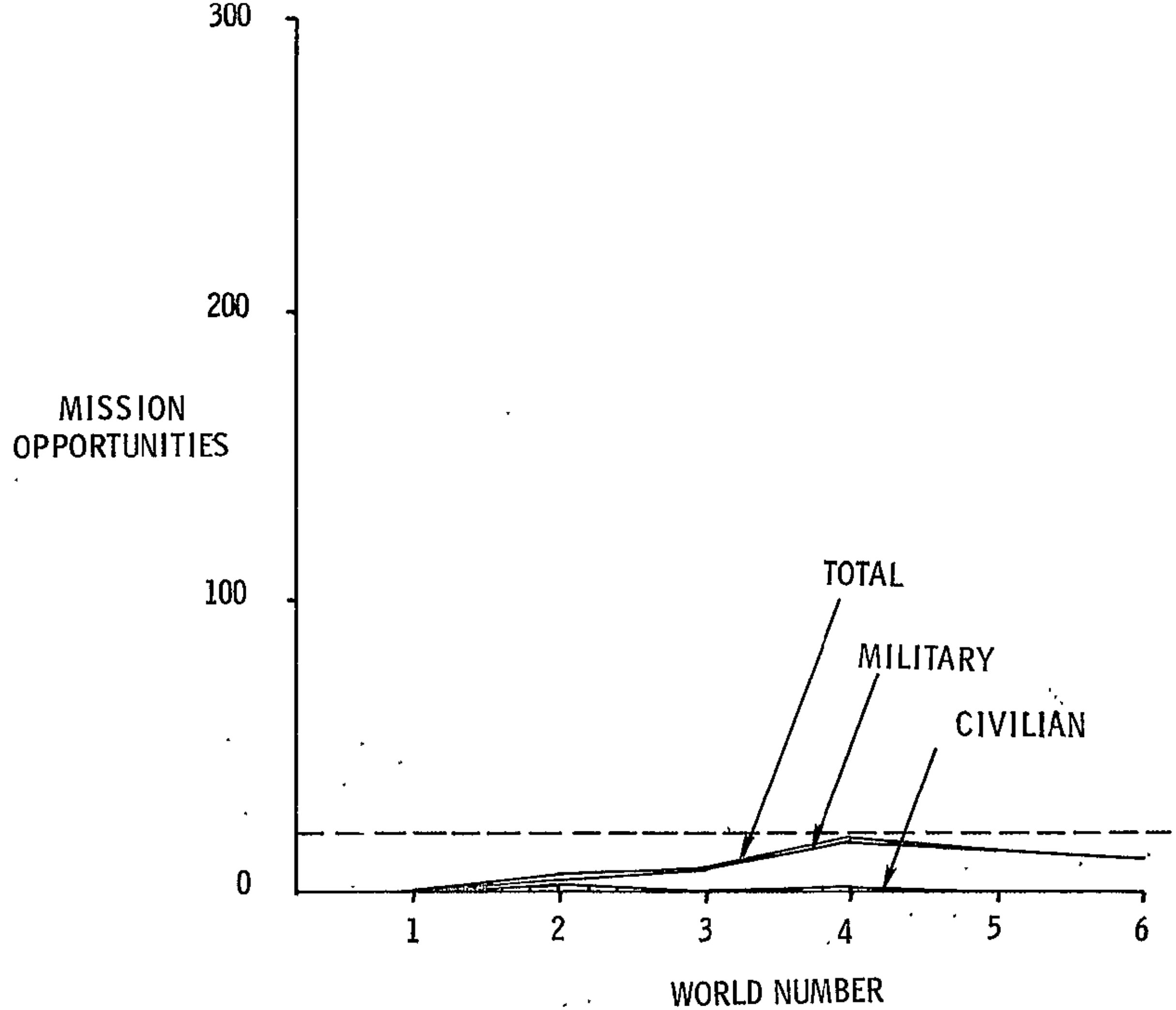
MISSION OPPORTUNITIES FOR SPACE FABRICATION



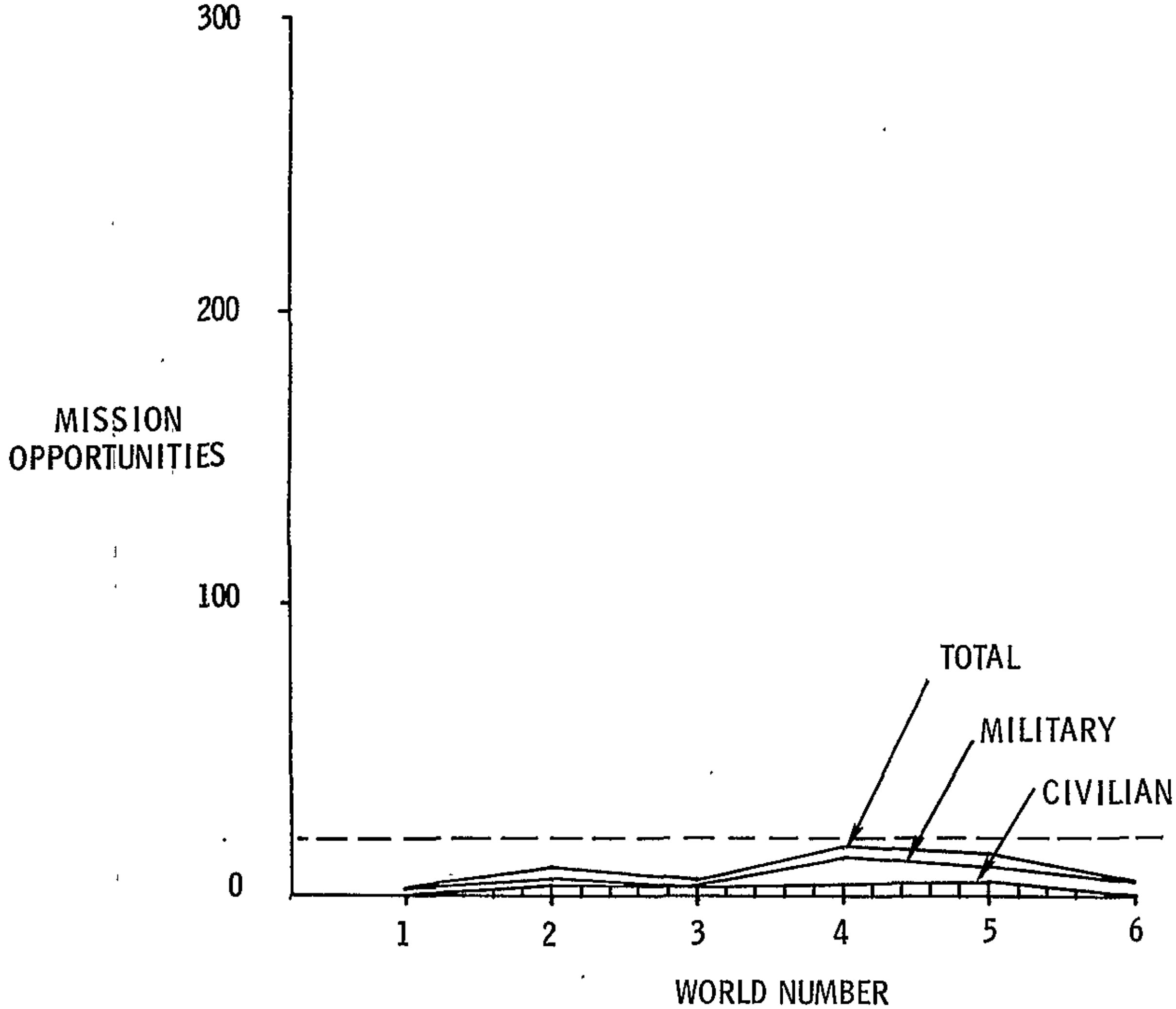


MISSION OPPORTUNITIES FOR HIGH POWER/ENERGY SOURCES
300
200
100
0
MISSION OPPORTUNITIES
TOTAL
CIVILIAN
MILITARY
1
2
3
4
5
6
WORLD NUMBER

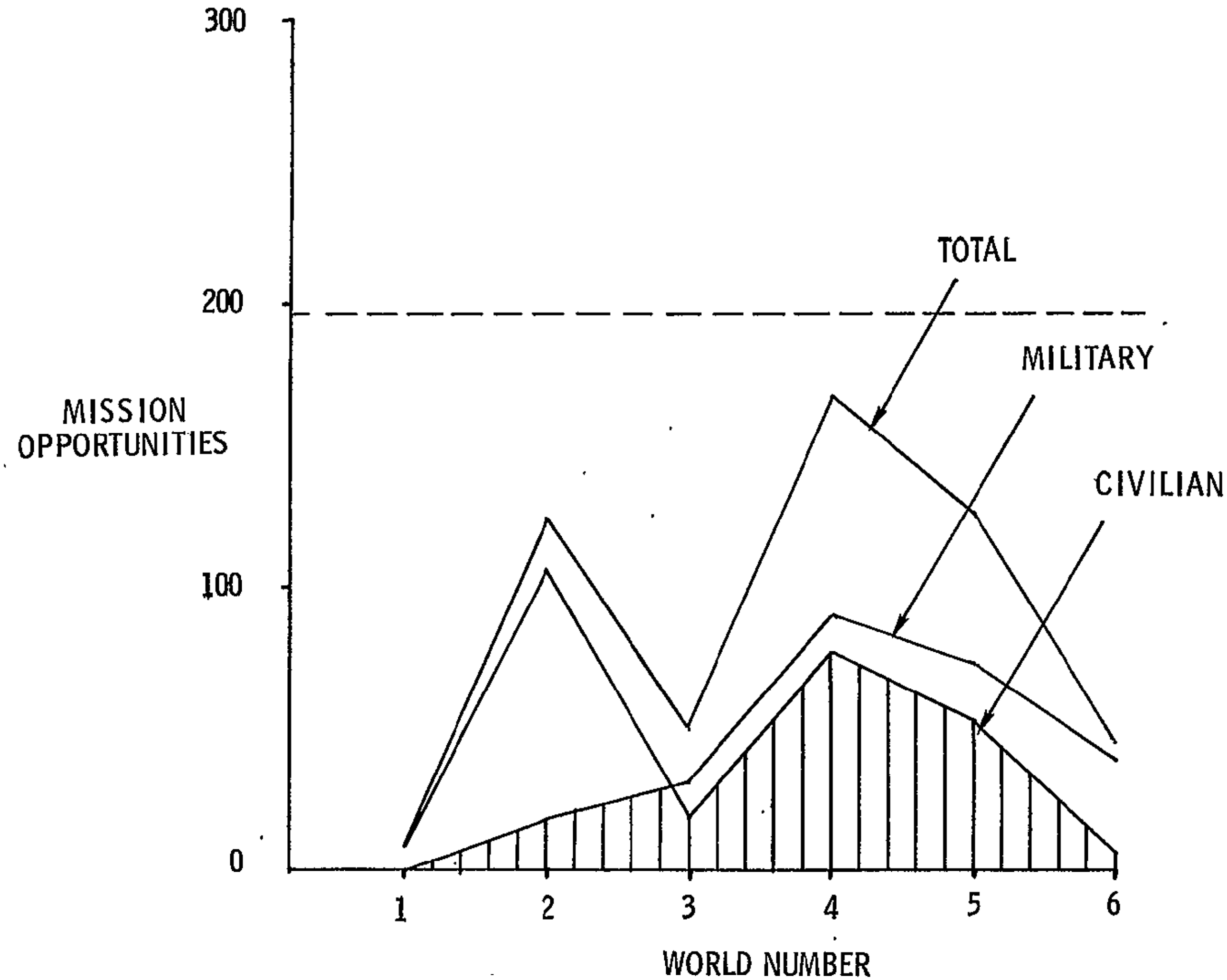
MISSION OPPORTUNITIES FOR HIGH ENERGY LASERS



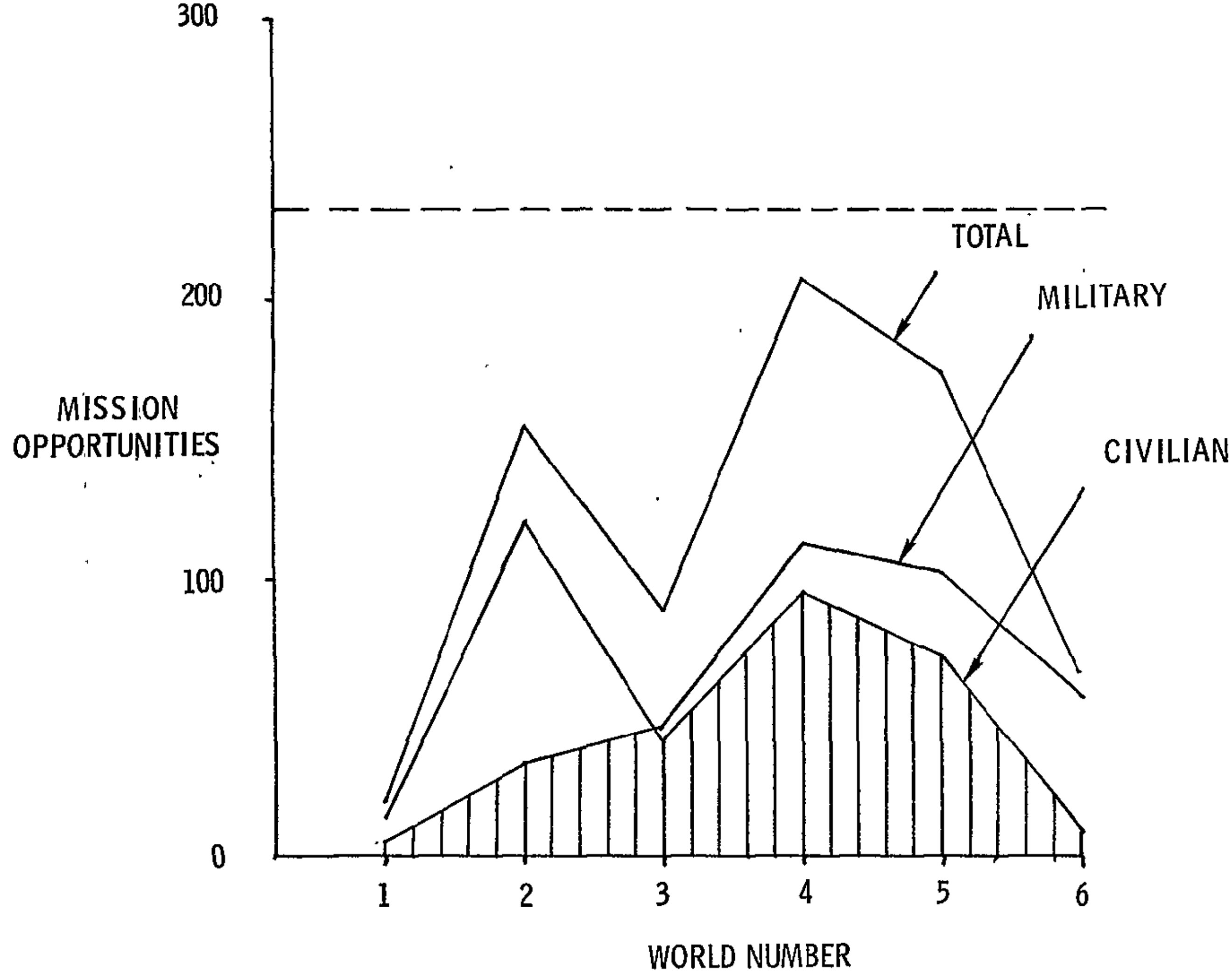
MISSION OPPORTUNITIES FOR HIGH POWERED RADARS



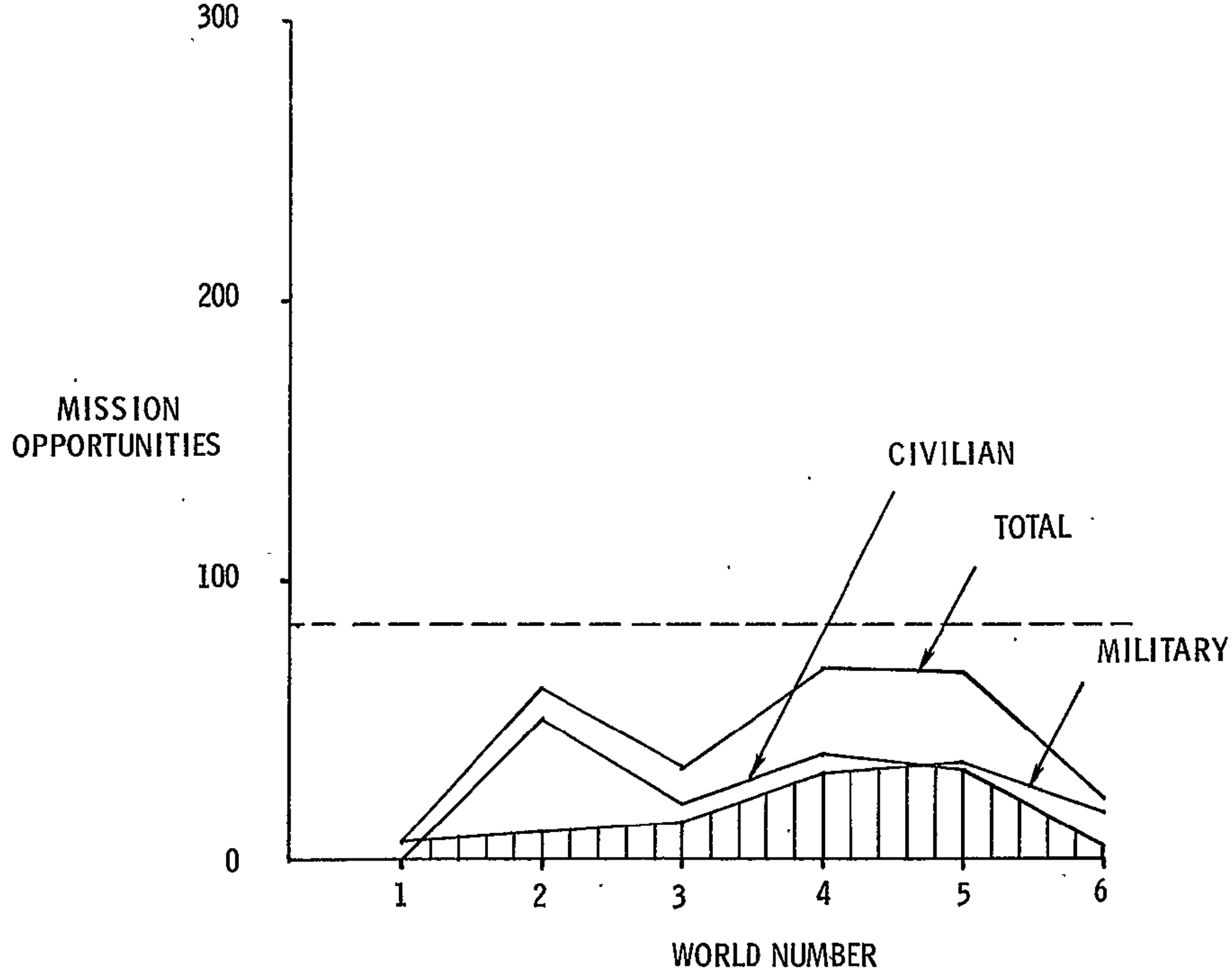
MISSION OPPORTUNITIES FOR PRECISE POINTING AND TRACKING



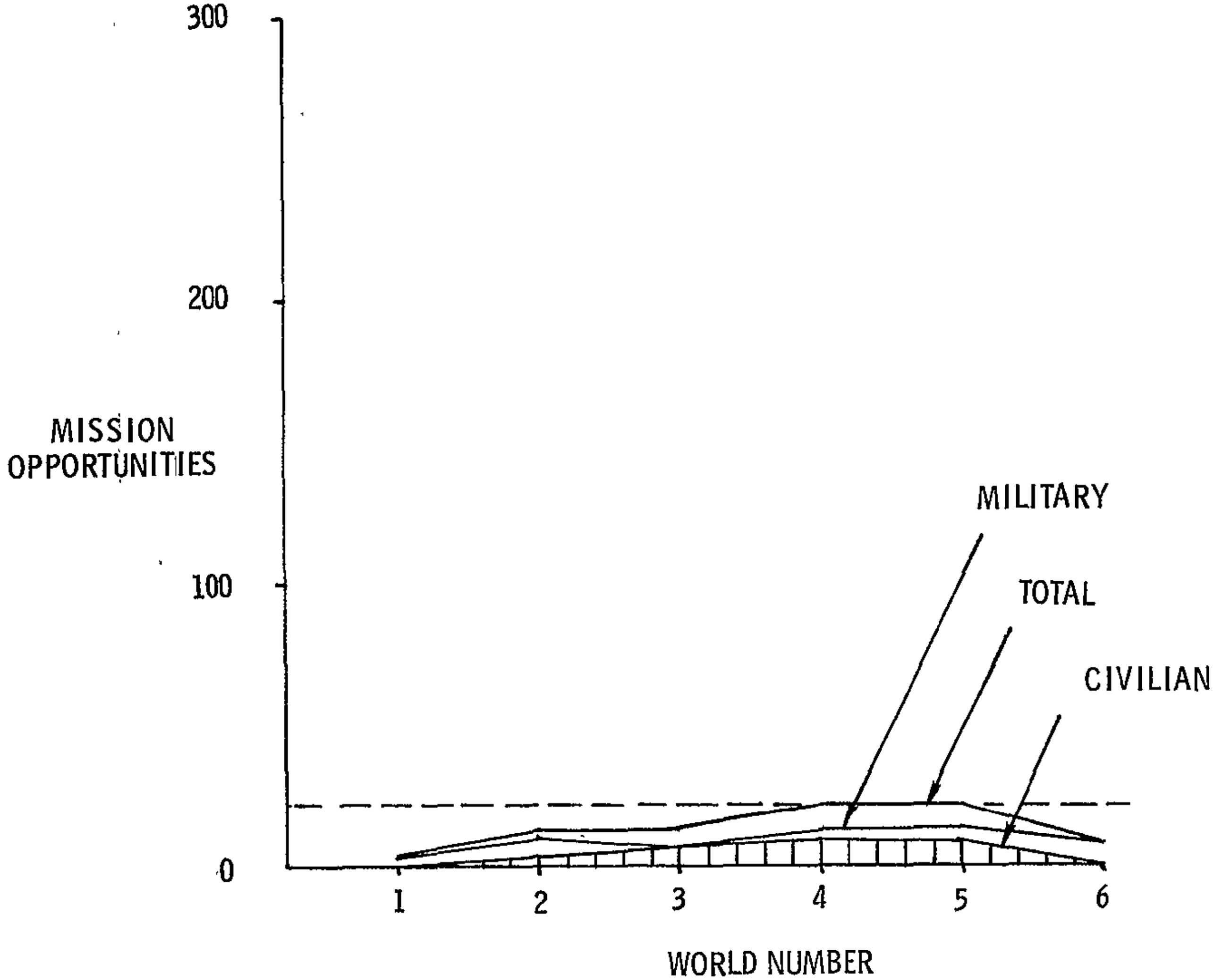
MISSION OPPORTUNITIES FOR LST COMPUTERS/PROCESSORS/DETECTORS



MISSION OPPORTUNITIES FOR MOSAIC/CCD FOCAL PLANES



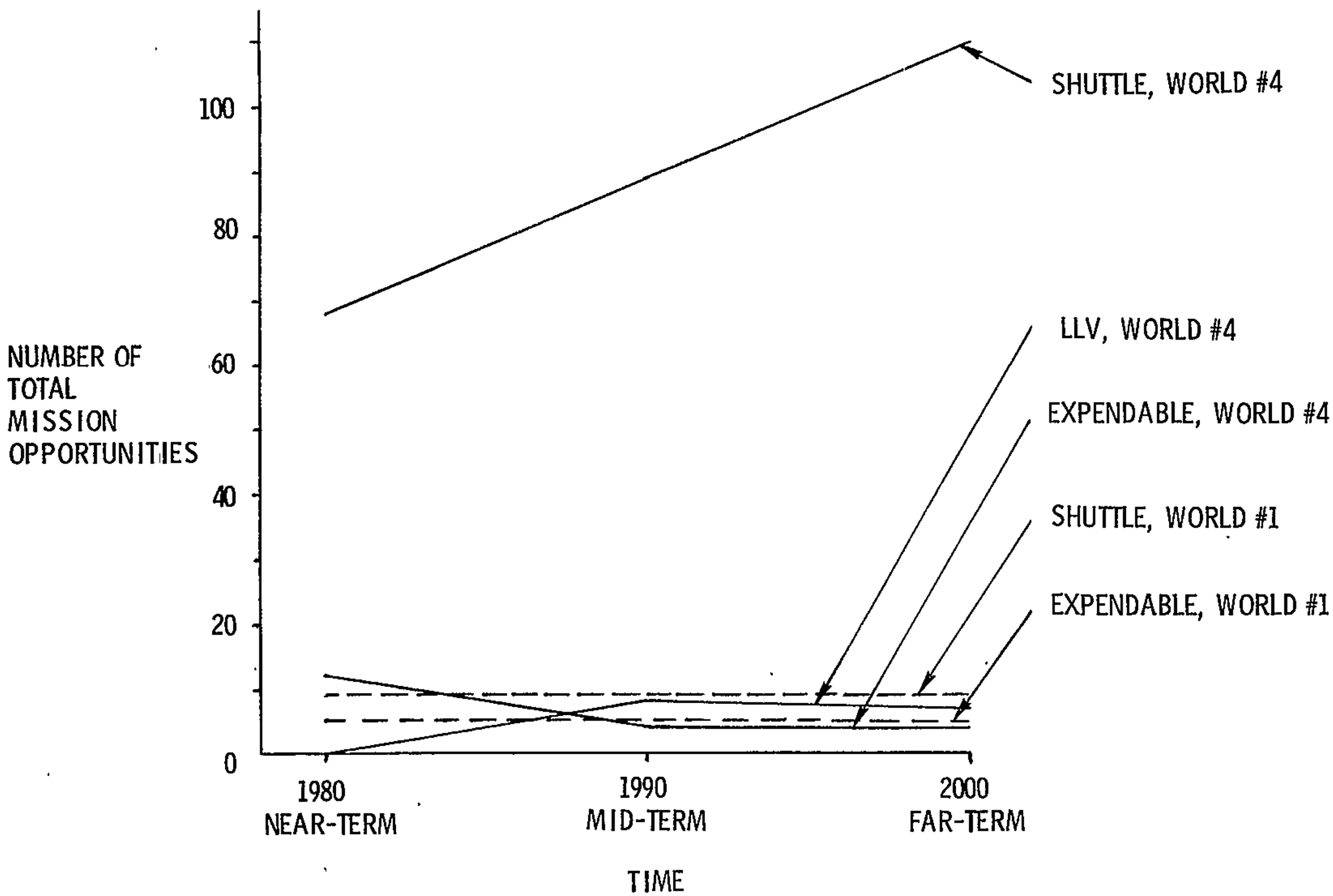
MISSION OPPORTUNITIES FOR CRYOGENIC REFRIGERATORS



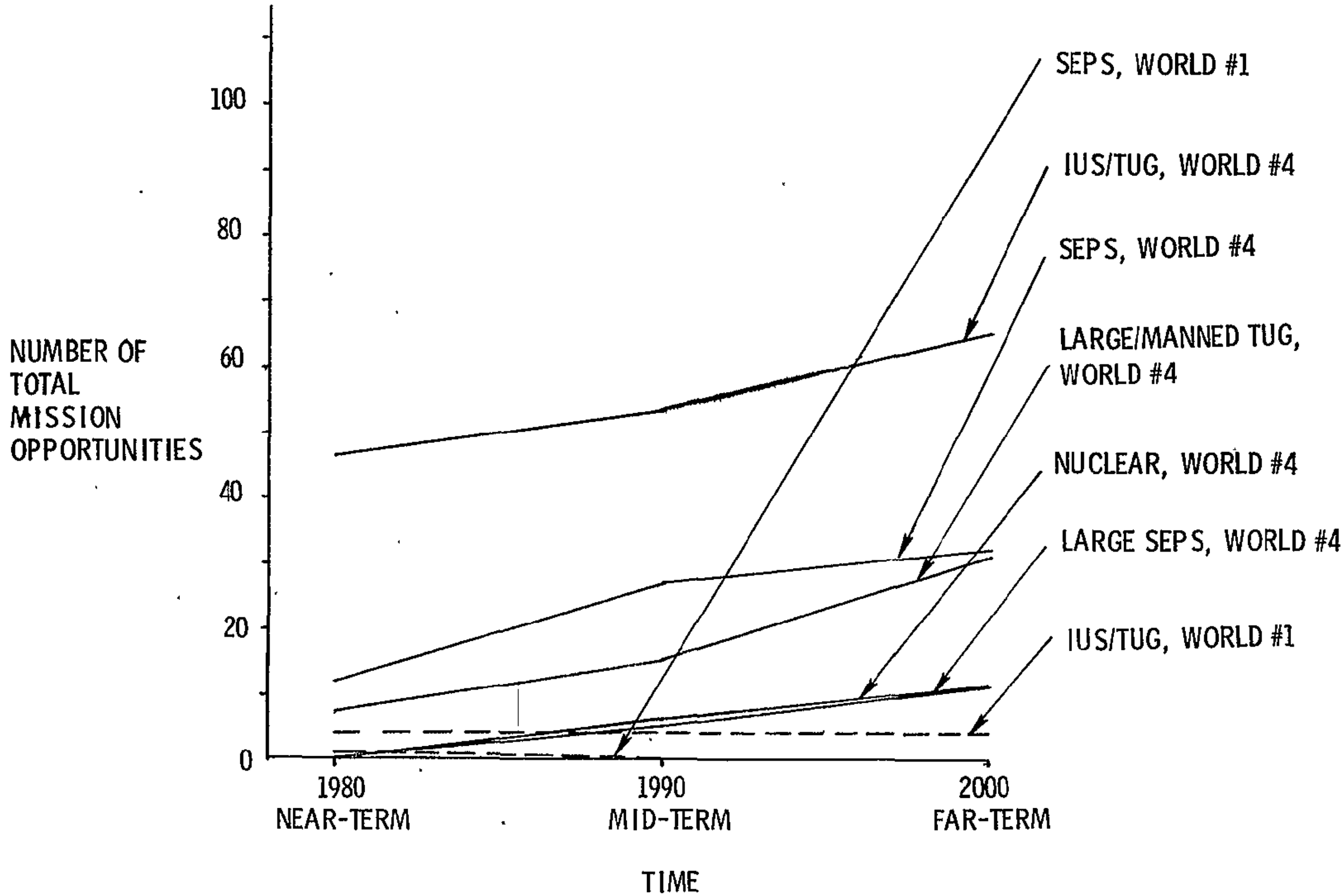
The following six sheets show the data on the opportunities for each building block and technology category for Worlds #1 and #4, presented as a function of time. It is seen that the opportunities generally are either flat or increase with time.

E-5711R1

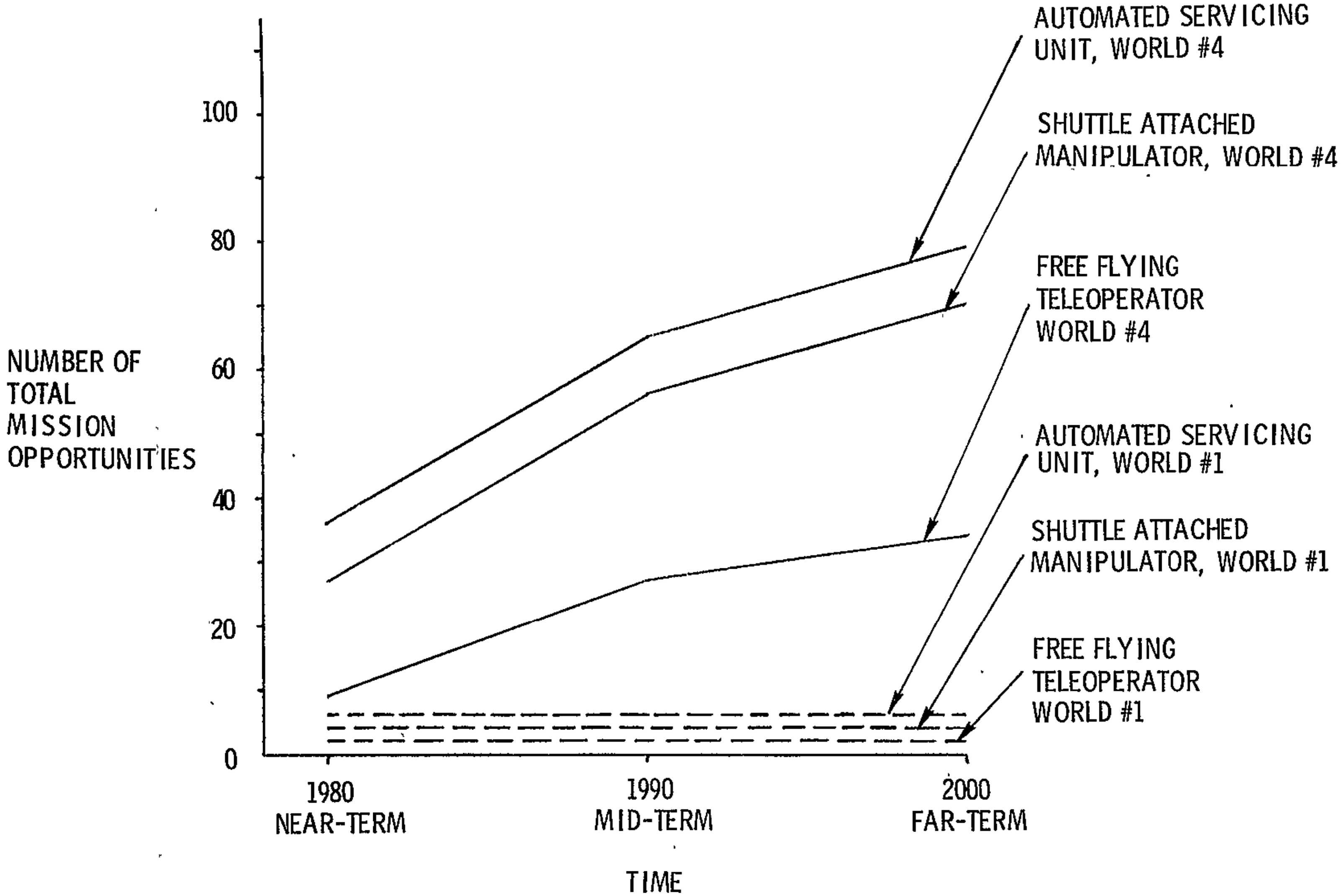
NUMBER OF MISSION OPPORTUNITIES FOR LOW EARTH ORBIT TRANSPORTATION



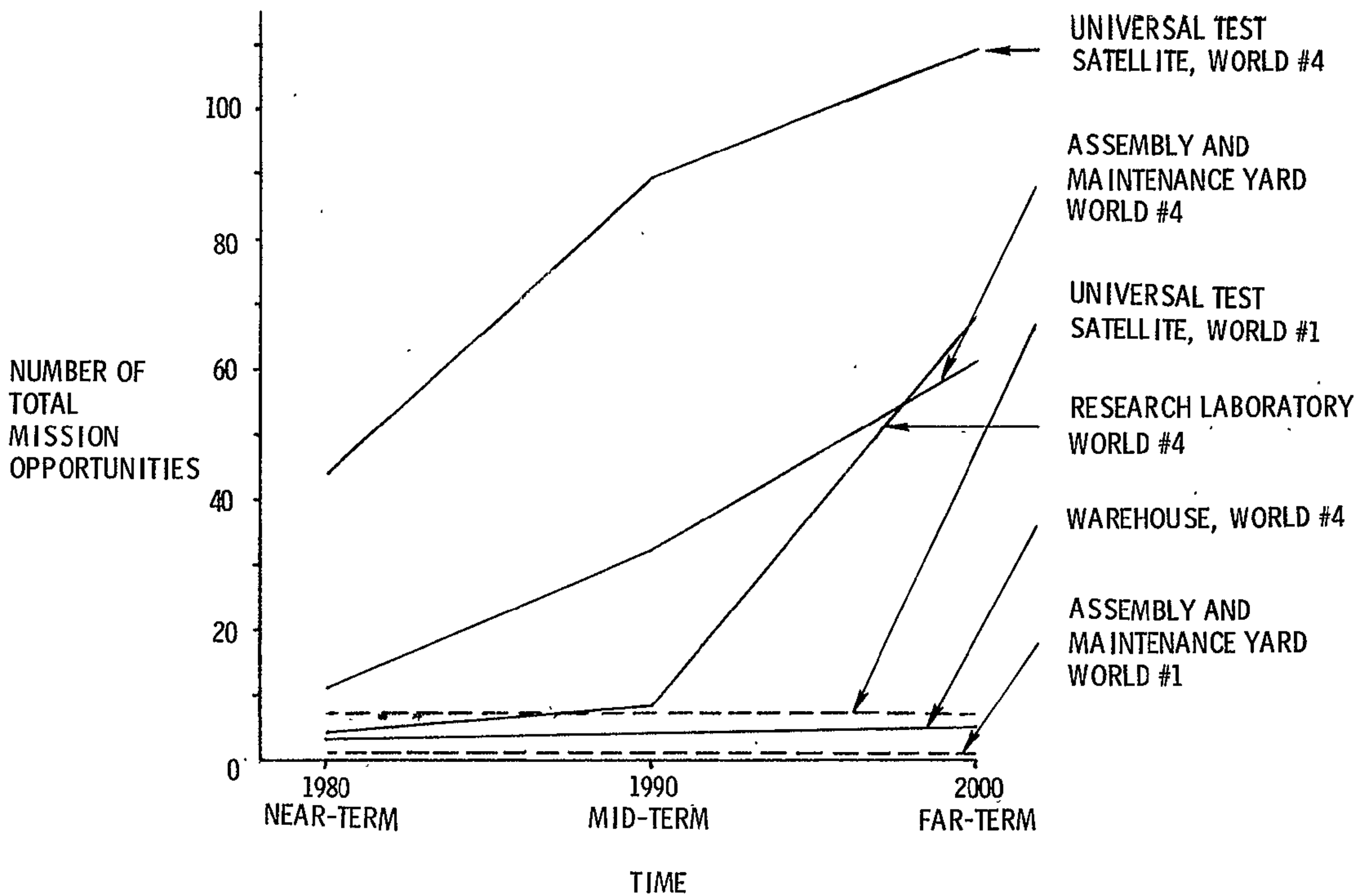
NUMBER OF MISSION OPPORTUNITIES FOR HIGH ORBIT/TRANSFER TRANSPORTATION



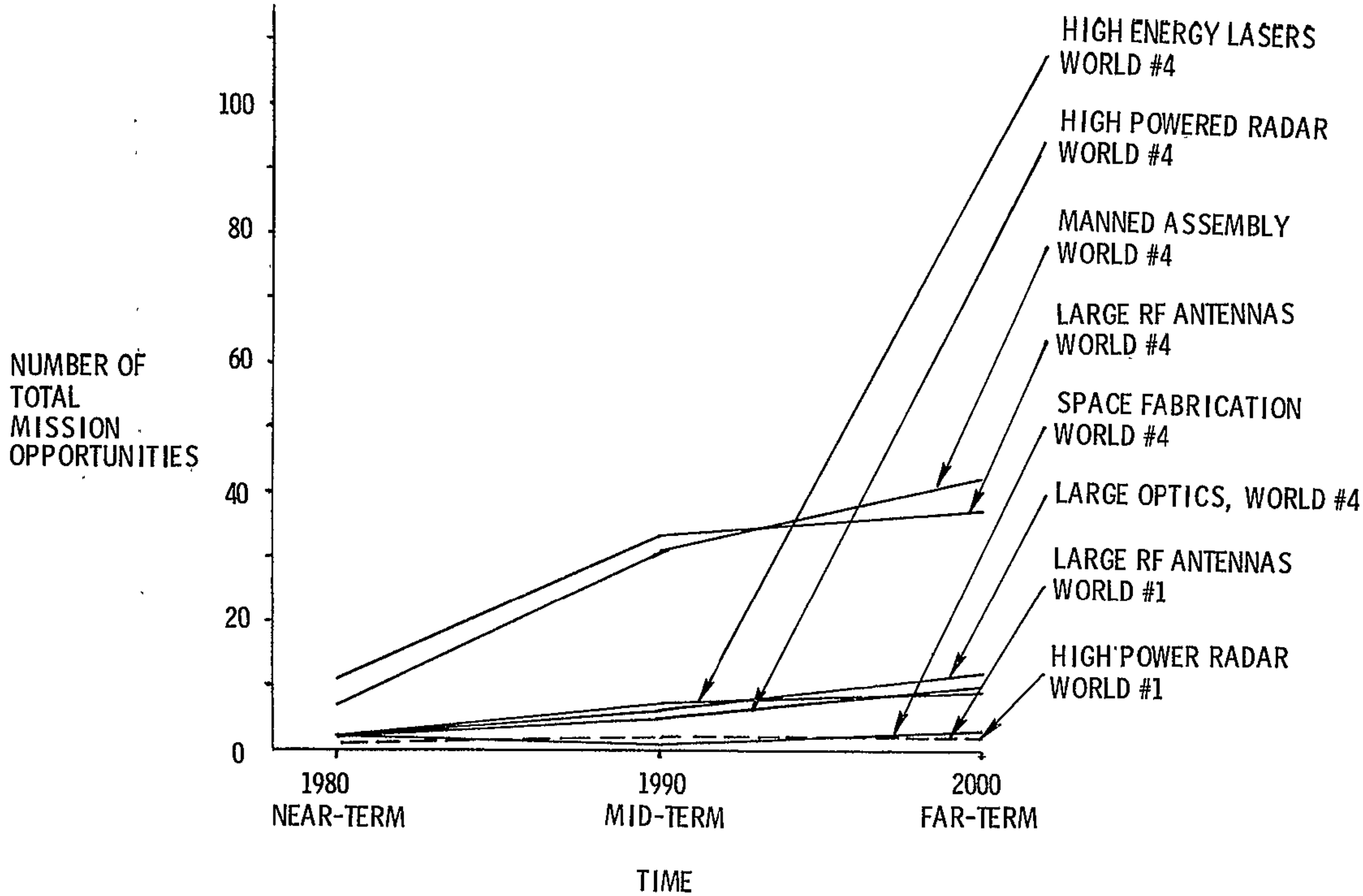
NUMBER OF MISSION OPPORTUNITIES FOR ORBITAL ASSEMBLY AND SERVICING STAGES



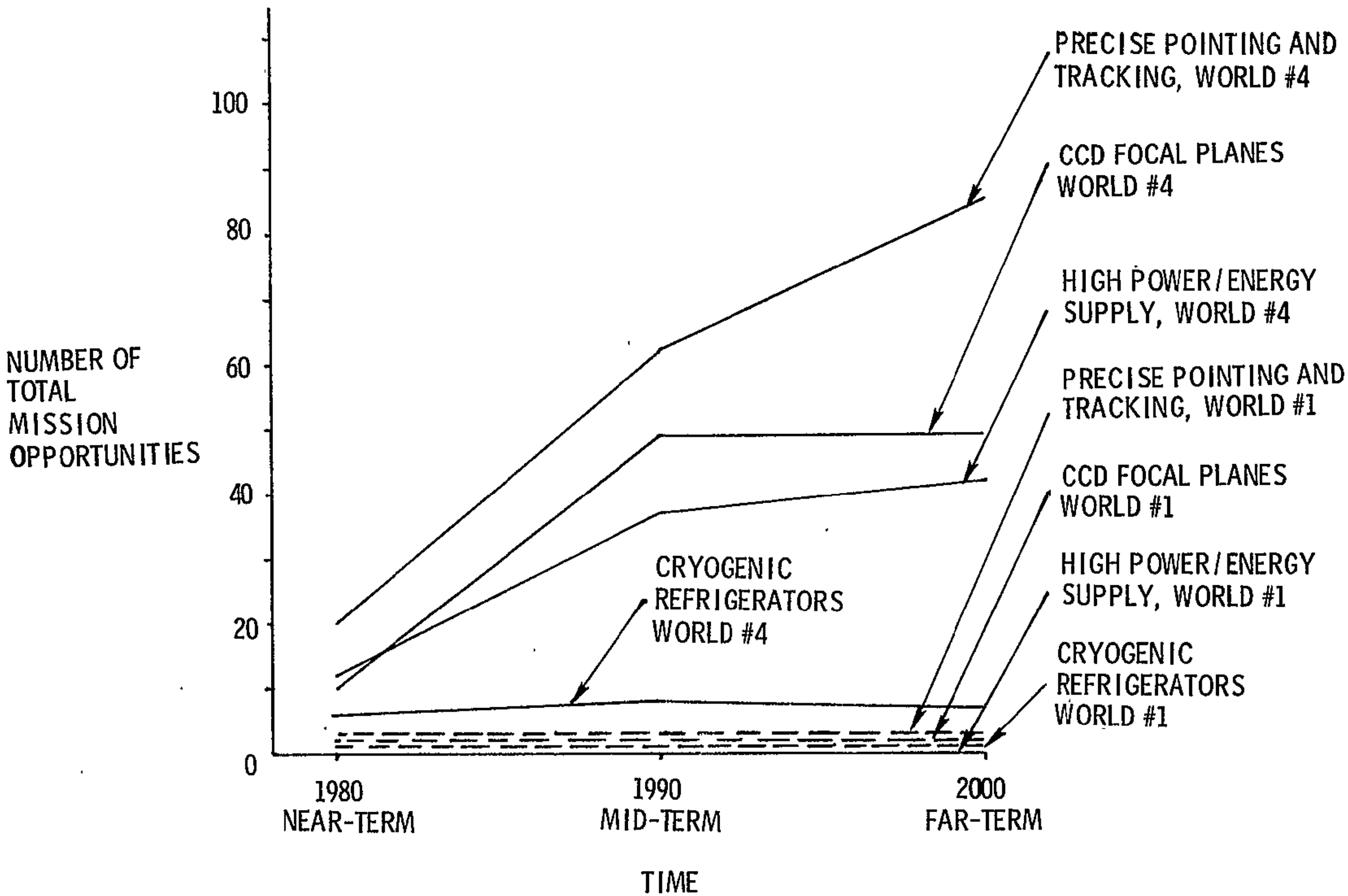
NUMBER OF MISSION OPPORTUNITIES FOR ORBITAL SUPPORT FACILITIES



NUMBER OF MISSION OPPORTUNITIES FOR ORBITAL TECHNIQUES AND TECHNOLOGY



NUMBER OF MISSION OPPORTUNITIES FOR ORBITAL TECHNIQUES AND TECHNOLOGY



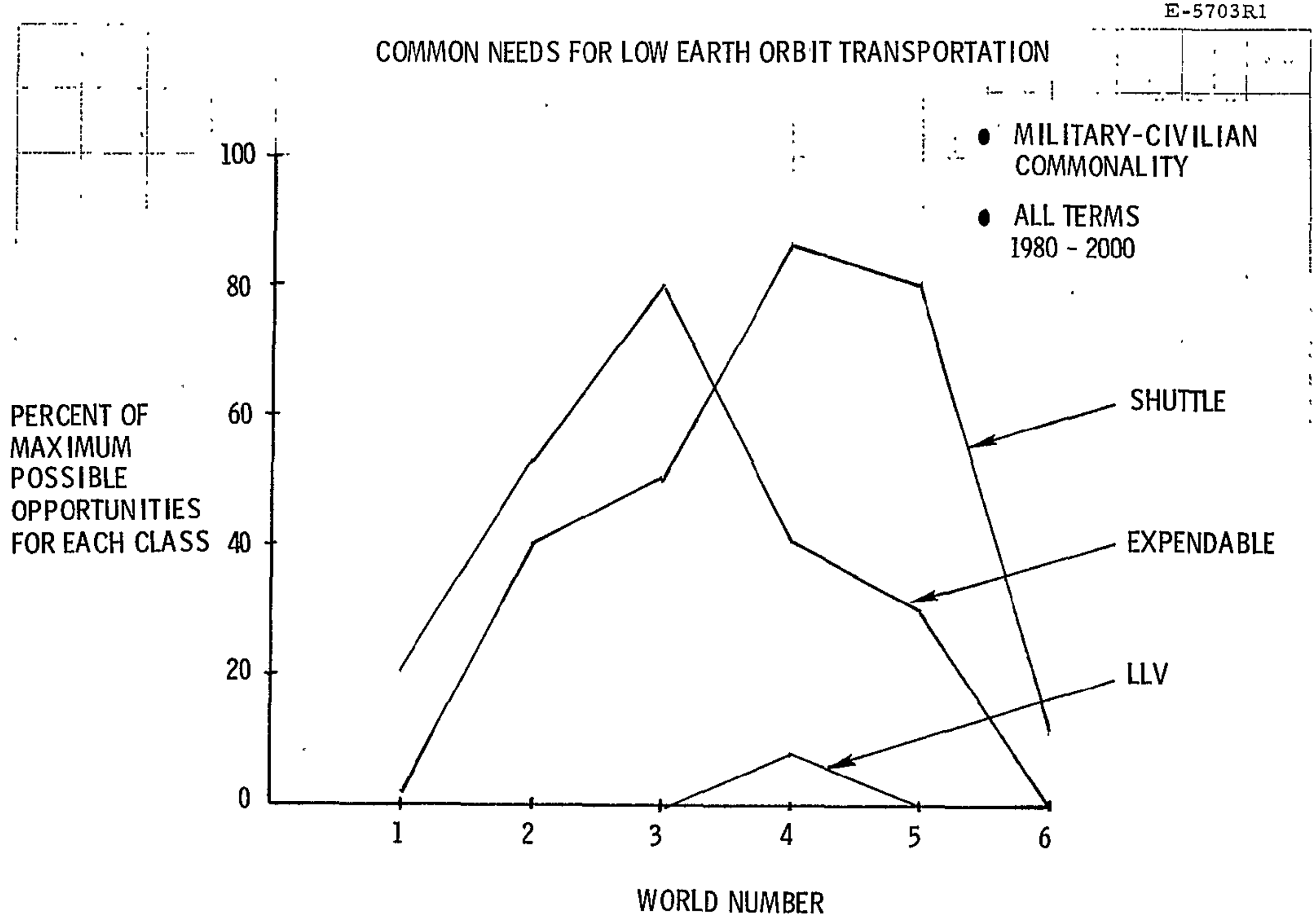
In the facing and following pages the results of the commonality investigation are summarized for ready interpretation of building block and technology needs. The data plotted in these graphs are the common needs for each class expressed as a percent of the maximum possible commonality. Reviewing the data of page 139, we see that if the military and civilian mission opportunities for a vehicle were equal and one half of the total, and if the total opportunities were equal to the maximum possible, that the common opportunities would be one half of the maximum possible and could be written as 50 percent. For normalization purposes, however, the commonality will be defined as twice the common needs divided by the maximum possible needs and expressed as percentage. Thus, in the figure on the facing page, it is seen that the shuttle common needs in World #4 are about 80 percent of the maximum possible needs. Thus, the commonality is expressed as a percentage of the maximum possible opportunities in the following graphs, whereas it was shown as the absolute number of common opportunities in the preceding graphs.

It is seen from the facing page that the commonality of the shuttle is high for Worlds #3, #4, and #5 and fairly high for Worlds #2 through #5, which are all the reasonable worlds. This is also the case for the expendable boosters. It is seen that the large lift vehicle has few common opportunities, as well as only a few percent common needs (and then only in World #4) with common needs being non-existent for any other world. This is because the large lift vehicle is only required for large far-term systems which are required primarily in World #2 by the civilian and in World #4 by the military, but only simultaneously in World #4. We can conclude that the shuttle, as well as any expendables

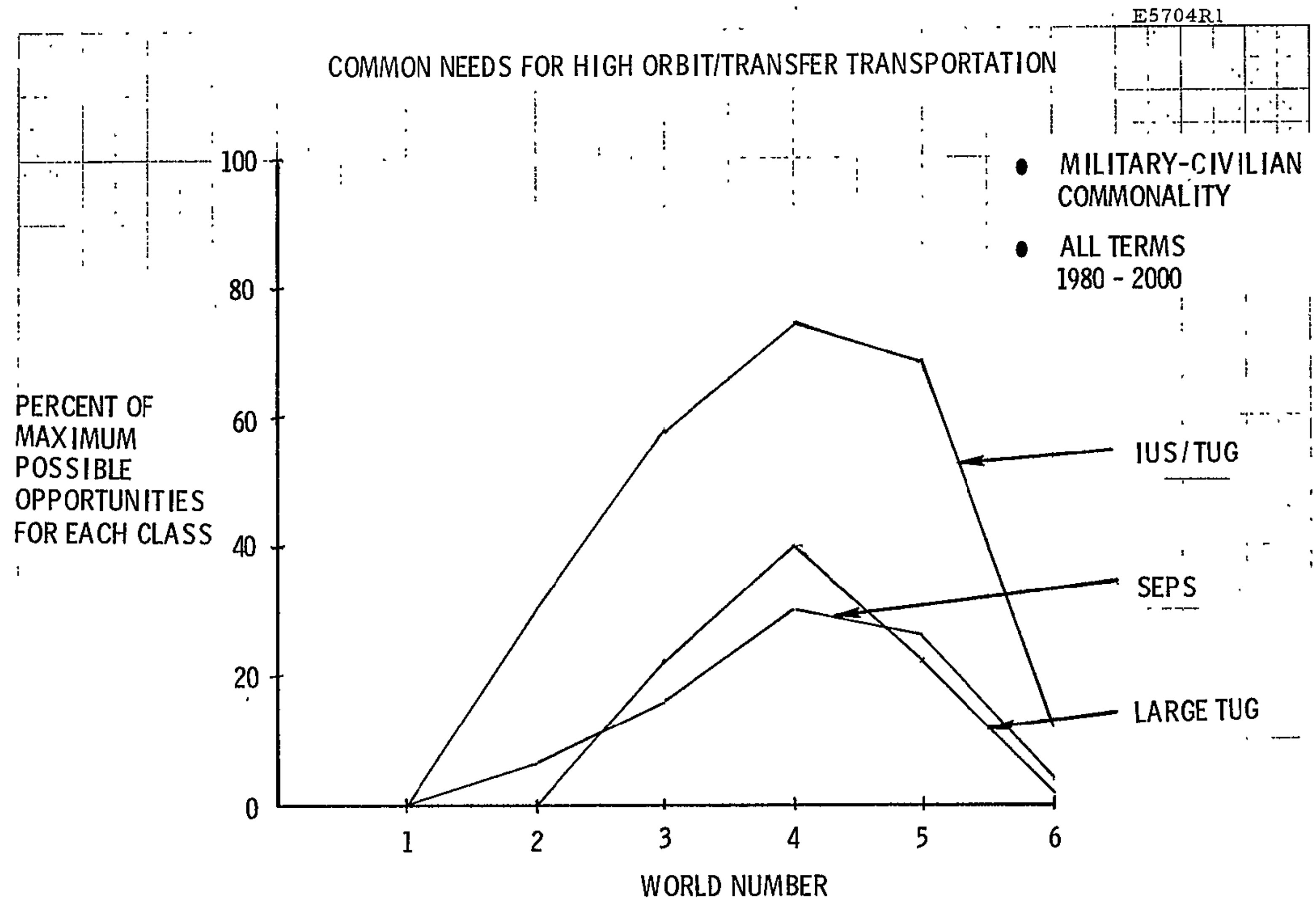
which may be needed, possess a high degree of commonality, whereas the large lift vehicle does not. This conclusion must be tempered with the statement that the launch vehicle requirements for the orbital support facilities themselves were not examined, and could well change the above conclusions. Furthermore, it must be remembered that even though the absolute and common opportunities for a given vehicle might be small, those missions could be judged extremely important, increasing the hazard of writing off any vehicle with small showing in these results.

E-5703R1

COMMON NEEDS FOR LOW EARTH ORBIT TRANSPORTATION



In the facing page the commonality curves are shown for high orbit and transfer transportation. It is seen that for all the reasonable worlds the IUS and tug have a large degree of commonality, followed very closely by the Solar Electric Propulsion Stage of 25 kW, and by a large or manned version of the tug. This is particularly true for Worlds #3, #4, and #5. World #6 also has some common needs whereas World #1 has none. Again this result follows inherently from the definitions of the scenarios of those worlds. It is to be noticed that there are no common needs for the nuclear stage since most needs for such a stage appear to stem from military requirements for prolonged and continuous maneuvering on orbit. (Civilian exploration of the Solar System and beyond were only very lightly treated in this study, and the latter conclusion could well be reversed upon their incorporation.)

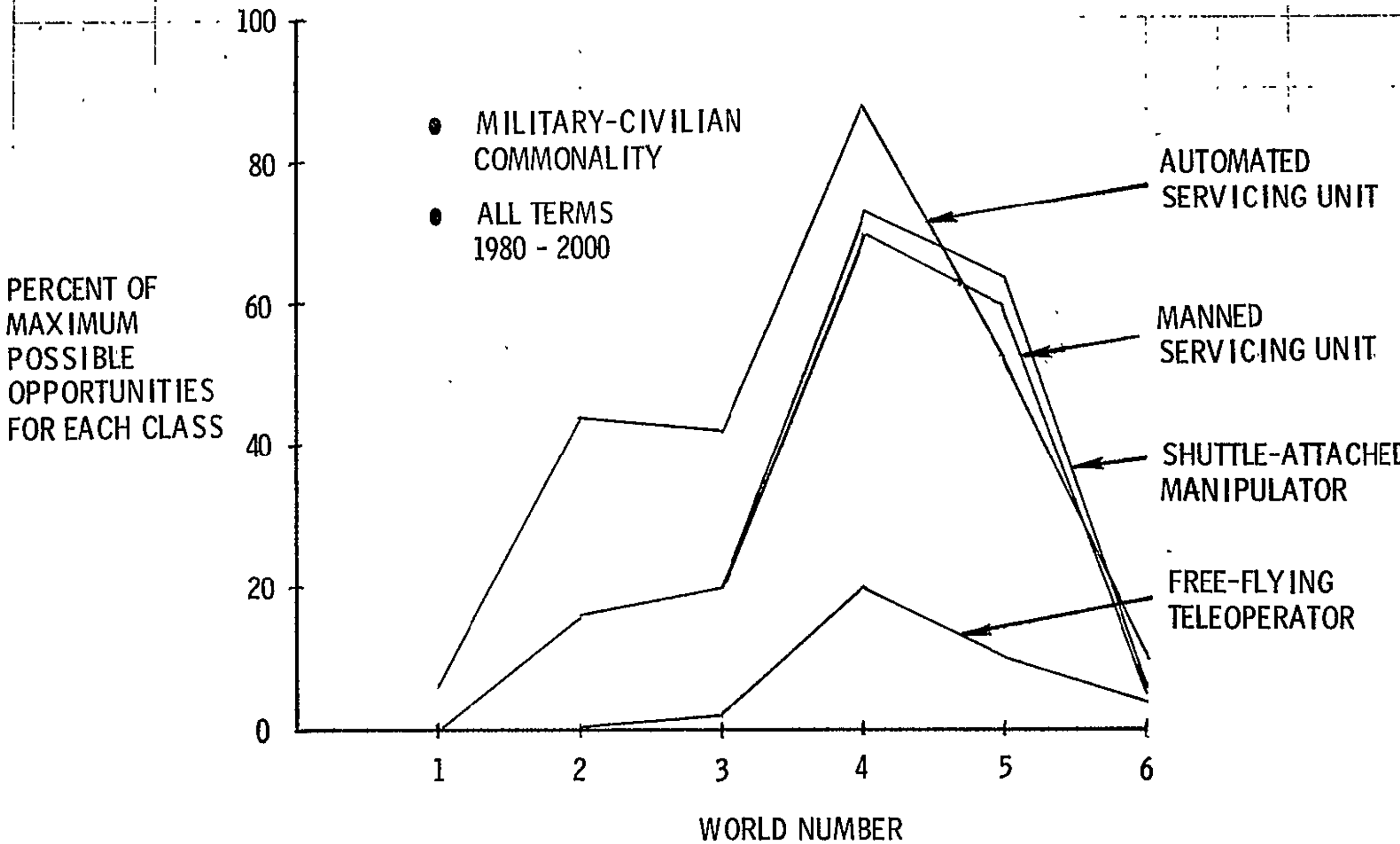


E5704R1
COMMON NEEDS FOR HIGH ORBIT/TRANSFER TRANSPORTATION
• MILITARY-CIVILIAN COMMONALITY
• ALL TERMS 1980 - 2000
PERCENT OF MAXIMUM POSSIBLE OPPORTUNITIES FOR EACH CLASS
100
80
60
40
20
0
1
2
3
4
5
6
WORLD NUMBER
IUS/TUG
SEPS
LARGE TUG

The graph on the facing page shows the common needs for assembly and servicing stages. The same trend is evident as for the transportation vehicles, with common needs being high for the automated and manned servicing units, as well as for the shuttle-attached manipulator (which is now a part of the baseline shuttle). These needs are high for the intermediate worlds. A free-flying teleoperator was also defined and is shown to have fewer possible common opportunities (though an automated assembly, servicing, and warehouse facility might rely extensively on such capability). The data on automated and/or manual assembly and servicing units makes a good case for developing such capability based on common NASA/DoD needs, quite aside from utility considerations pertaining to any one particular system application.

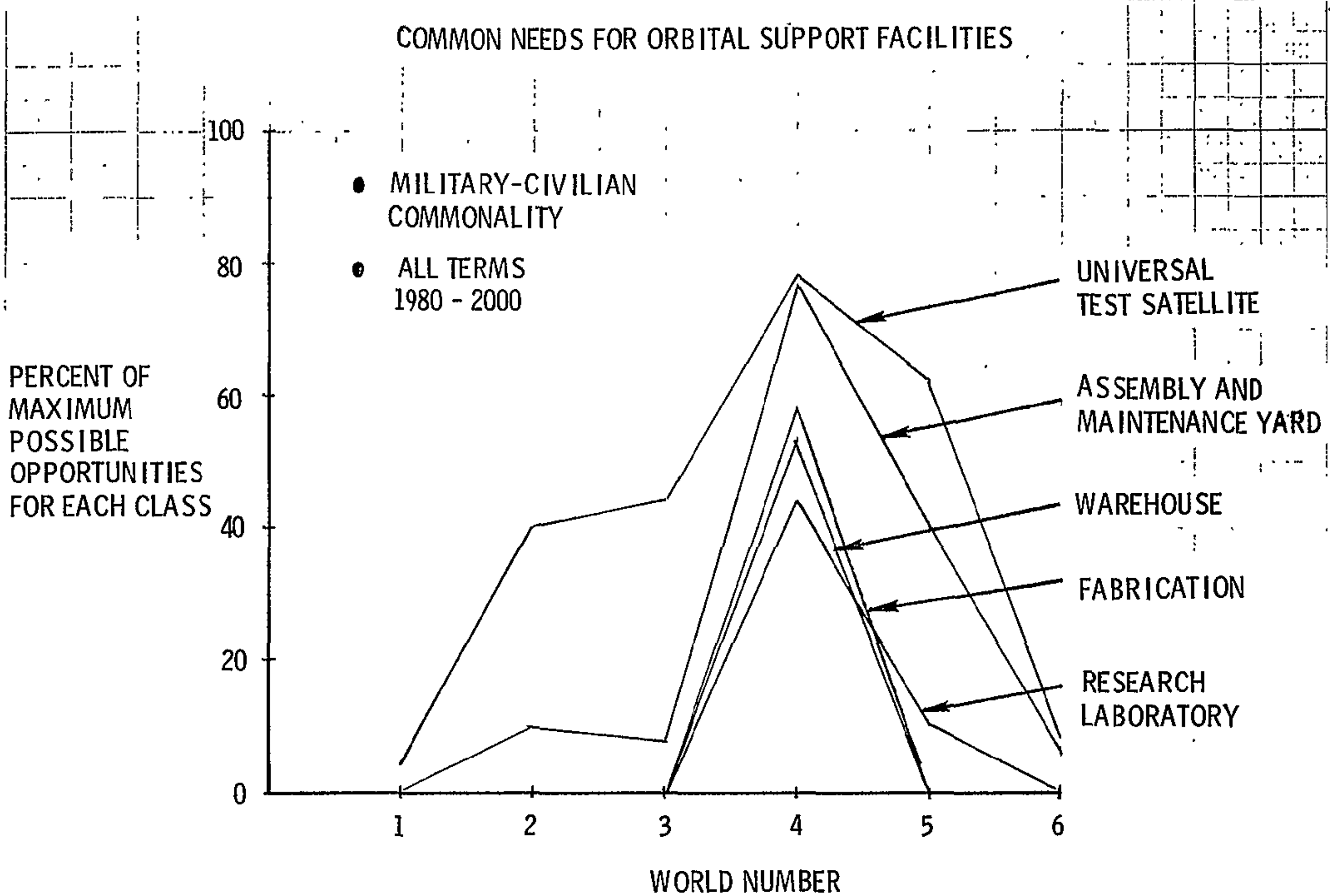
E5705R1

COMMON NEEDS FOR ASSEMBLY AND SERVICING STAGES



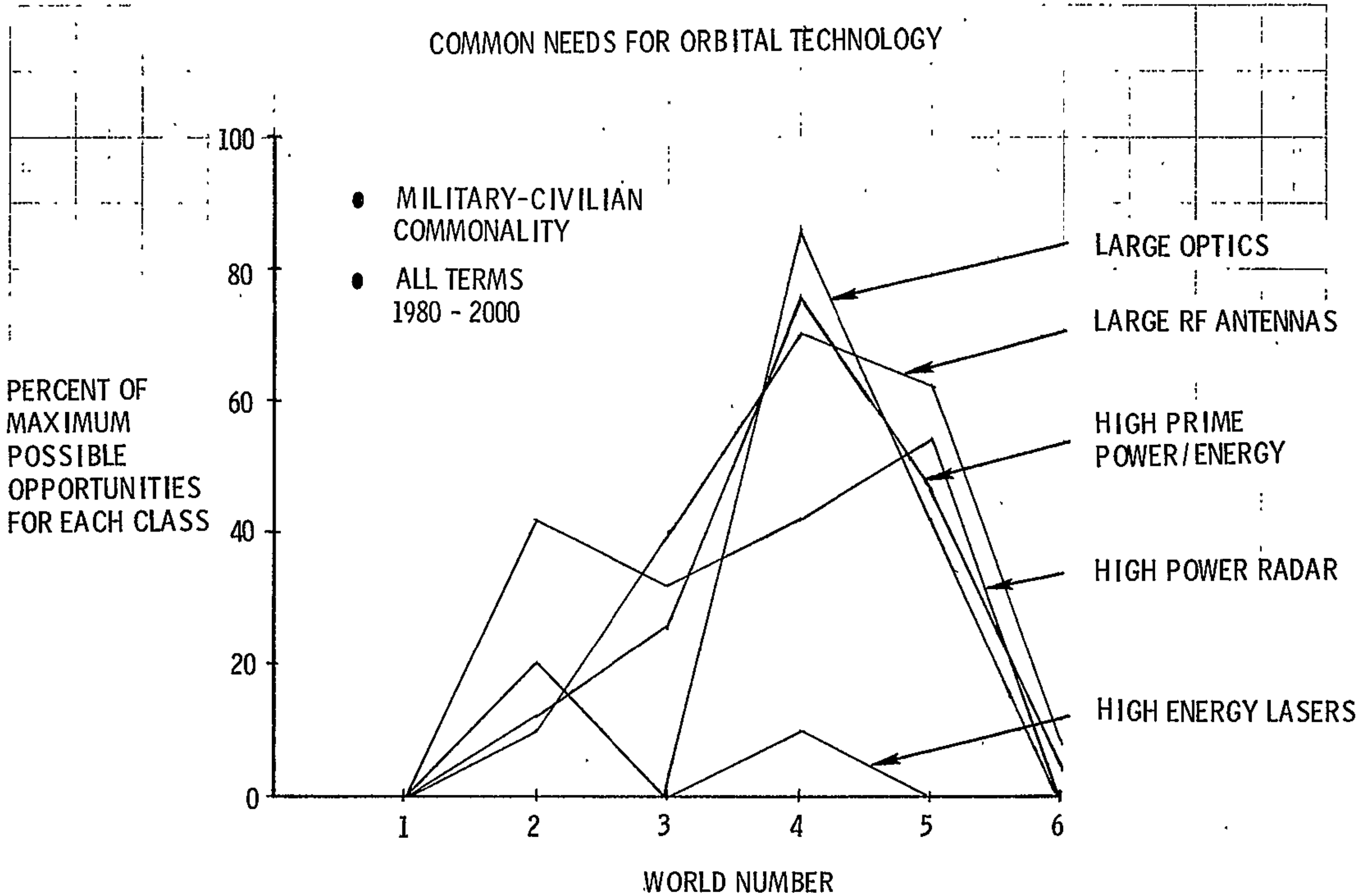
Common needs for orbital support facilities are shown on the graph on the facing page. It is seen that a universal test satellite (free-flying test laboratory) has a very high commonality in most of the reasonable worlds, with assembly and maintenance facilities having high commonality primarily in Worlds #4, and #5, although having some degree of commonality also in Worlds #2 and #3. Warehousing, fabrication, and research laboratories do not possess commonality in Worlds #1, #2, and #6. In particular, warehousing and fabrication is only shown to have commonality in World #4. Thus, common need for orbital support facilities is very high in World #4, as expected. These support facilities could be manned, automated, or telefactor operated, as no distinction is made in this study. Again, by proper definition of the components of such facilities, some of the above conclusions could be modified.

E5706R1



COMMON NEEDS FOR ORBITAL SUPPORT FACILITIES
MILITARY-CIVILIAN COMMONALITY
ALL TERMS 1980 - 2000
PERCENT OF MAXIMUM POSSIBLE OPPORTUNITIES FOR EACH CLASS
100
80
60
40
20
0
1
2
3
4
5
6
WORLD NUMBER
UNIVERSAL TEST SATELLITE
ASSEMBLY AND MAINTENANCE YARD
WAREHOUSE
FABRICATION
RESEARCH LABORATORY

Common needs for orbital technology are shown on the graphs of the facing page and following page. It is seen that large RF/microwave antennas and high power radar have the highest degree of commonality for all worlds, whereas large optics and high energy lasers possess a high degree of commonality only in Worlds #5 and #6, with a minor peak in the relatively benign World #2. World #3 has no common requirements for lasers or large optics, nor does World #1. The low commonality for high energy lasers is to be expected, since they find few civilian applications other than powering of aircraft, whereas there are many military applications. The communications and radar applications, however, find missions in both civilian observation of surface features and aircraft tracking and in the military equivalents, resulting in a fair degree of commonality.

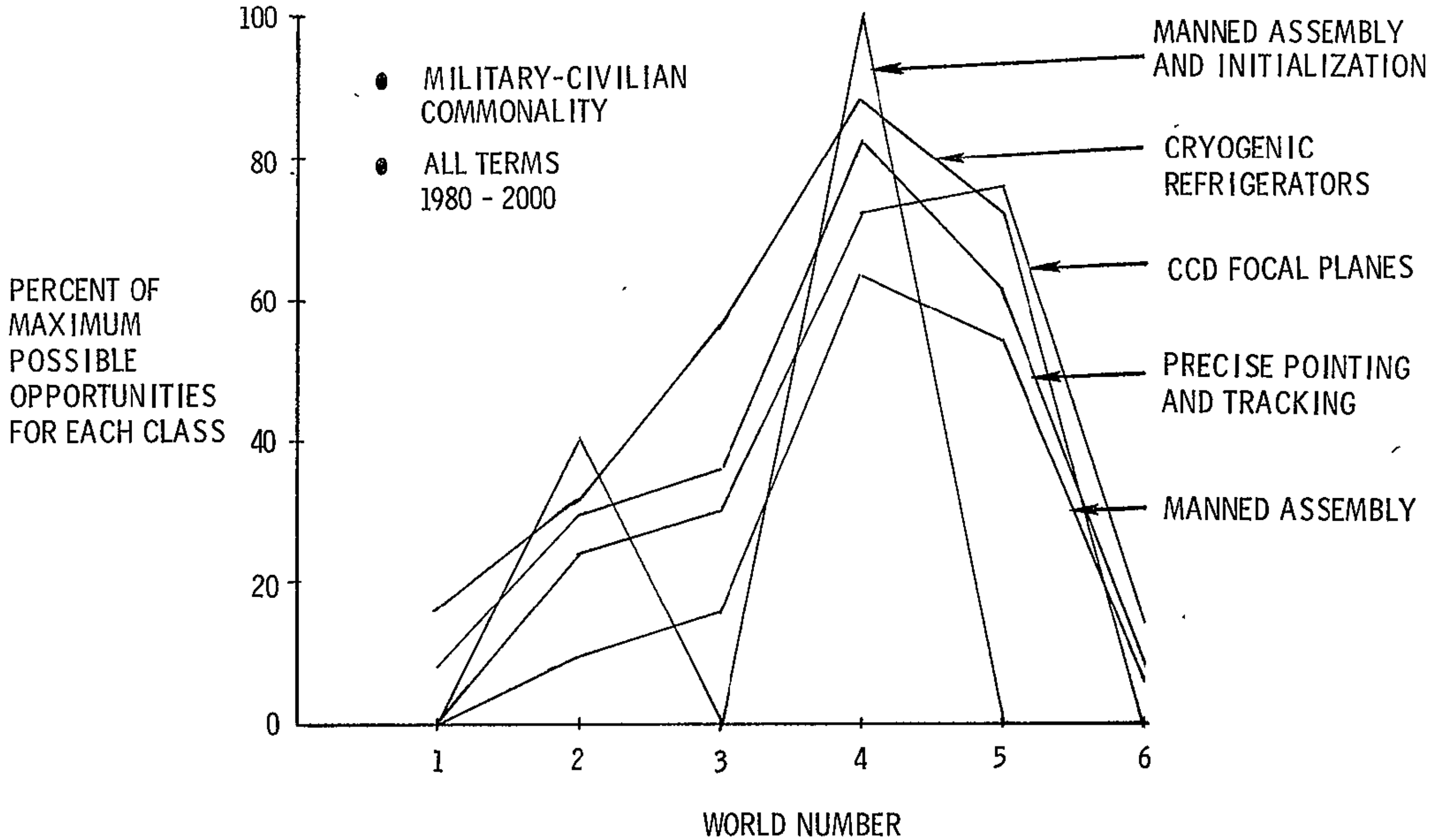


COMMON NEEDS FOR ORBITAL TECHNOLOGY
MILITARY-CIVILIAN COMMONALITY
ALL TERMS 1980 - 2000
PERCENT OF MAXIMUM POSSIBLE OPPORTUNITIES FOR EACH CLASS
100
80
60
40
20
0
1
2
3
4
5
6
WORLD NUMBER
LARGE OPTICS
LARGE RF ANTENNAS
HIGH PRIME POWER/ENERGY
HIGH POWER RADAR
HIGH ENERGY LASERS

The remainder of the common requirements for orbital techniques and technology are summarized on the facing page. It is seen that the same trend applies as for the previous graph with all of the technologies having a common need peaking in Worlds #3, #4, and #5, with a reduction in needs for the more extreme worlds. It is noteworthy that space fabrication has 100 percent common application in World #4, and would make a case for such capability were it not for the small absolute number of opportunities in which it was identified. That may reflect incomplete treatment of the topic by the study team more than any judgment on the topic.

E-5708R2

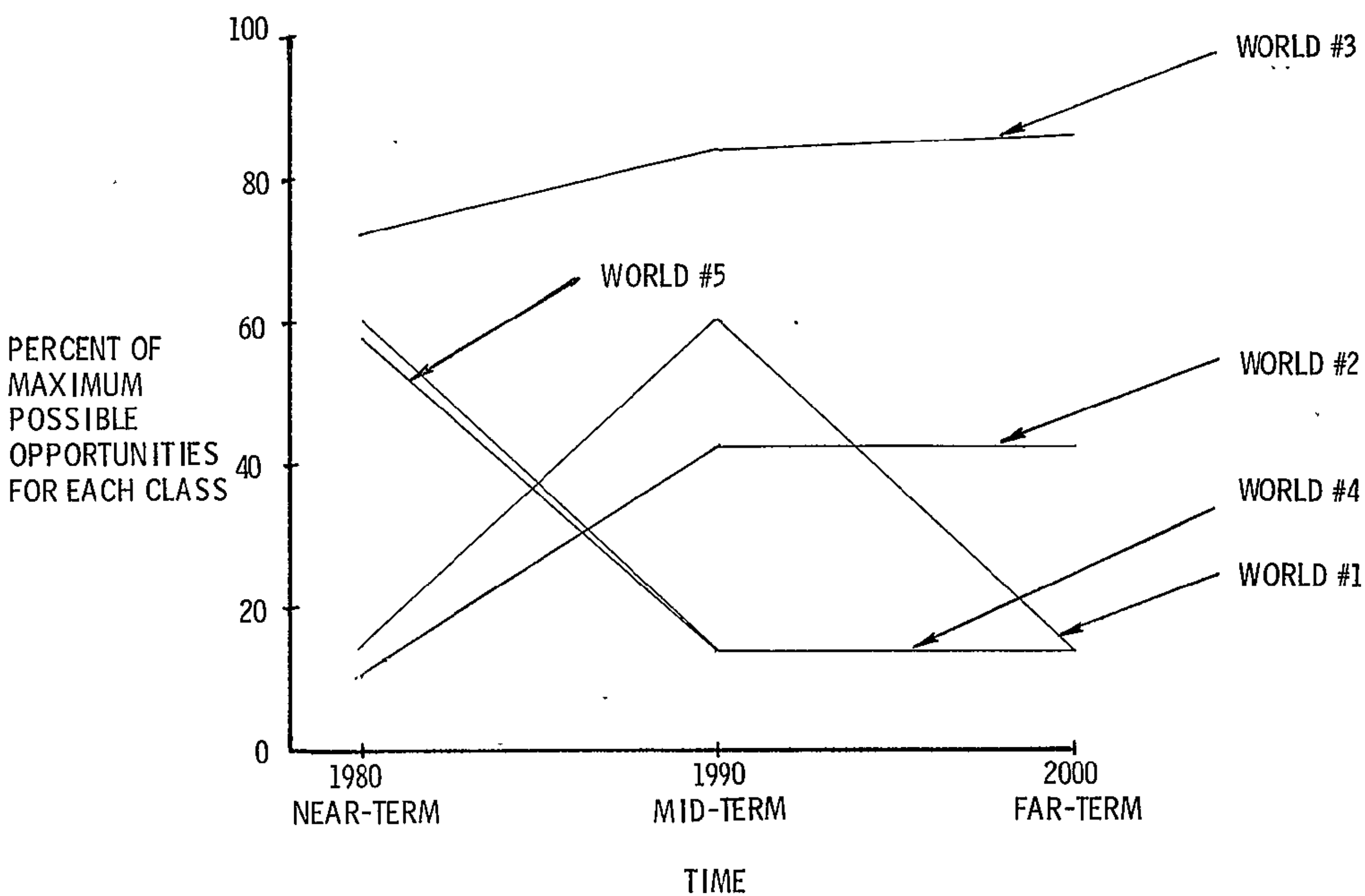
COMMON NEEDS FOR ORBITAL TECHNIQUES AND TECHNOLOGY



The following graphs show the common needs for each of the building block vehicles and technologies for each world, as a function of time.

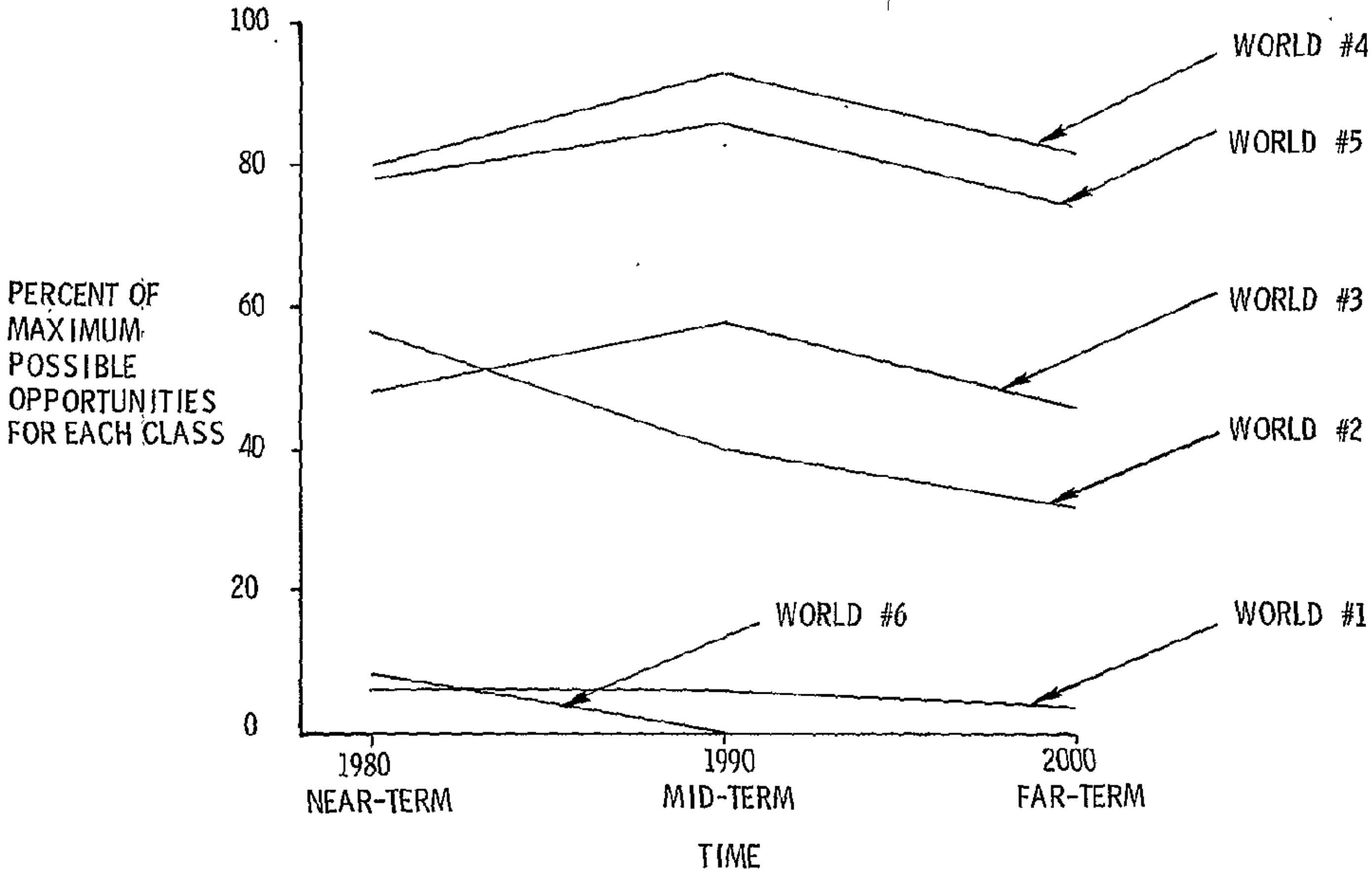
It will be noted that there are no common needs in all worlds for the large launch vehicle, the large SEPS, and the nuclear stage. Also other building blocks and technologies have no common needs in certain worlds. The commonalities will be seen to be fairly flat as a function of time, and to be at a higher percentage level for Worlds #4 and #5 than for the other worlds.

COMMON NEEDS FOR THE EXPENDABLE BOOSTERS

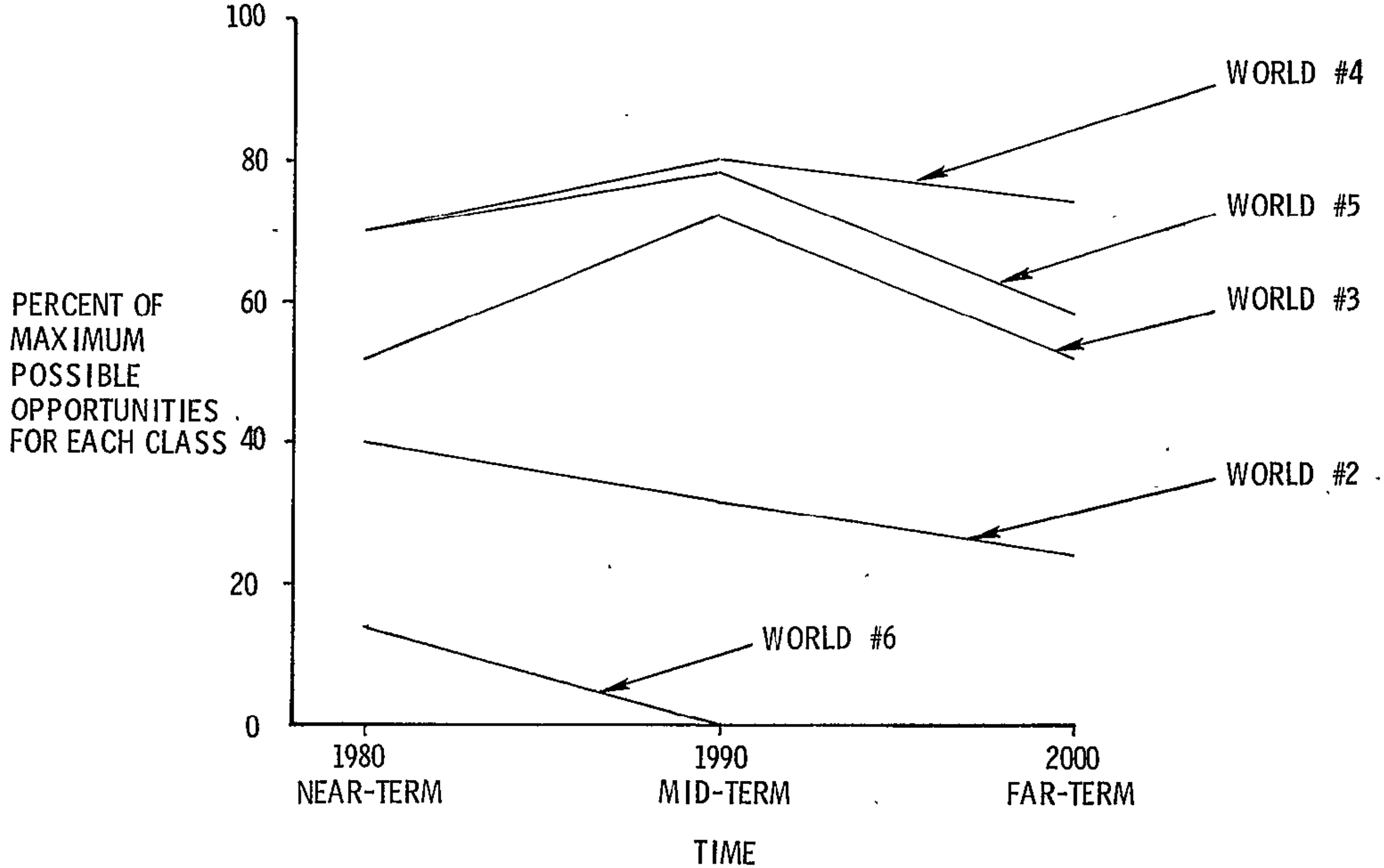


E-5709R2

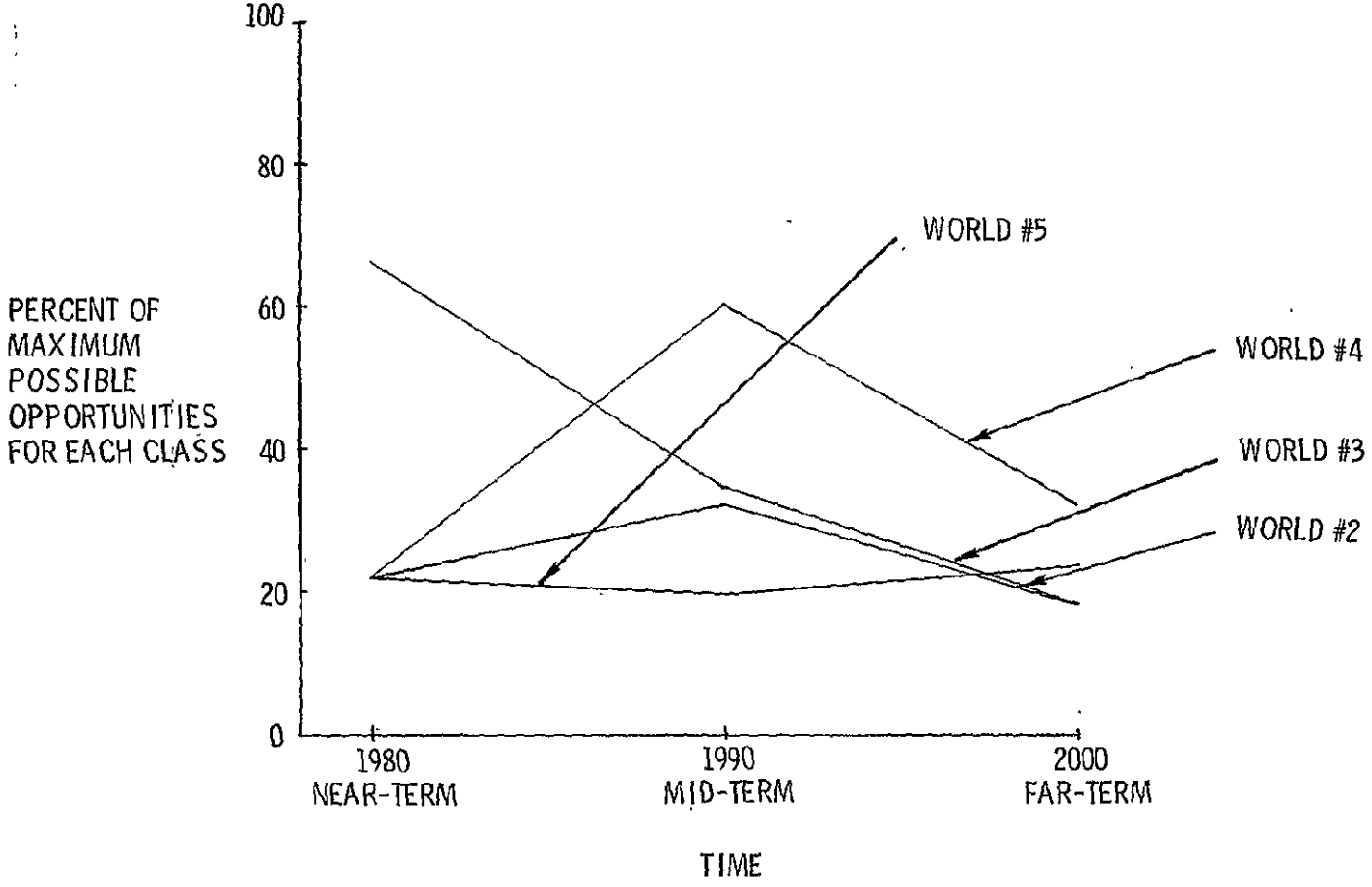
COMMON NEEDS FOR THE SPACE SHUTTLE



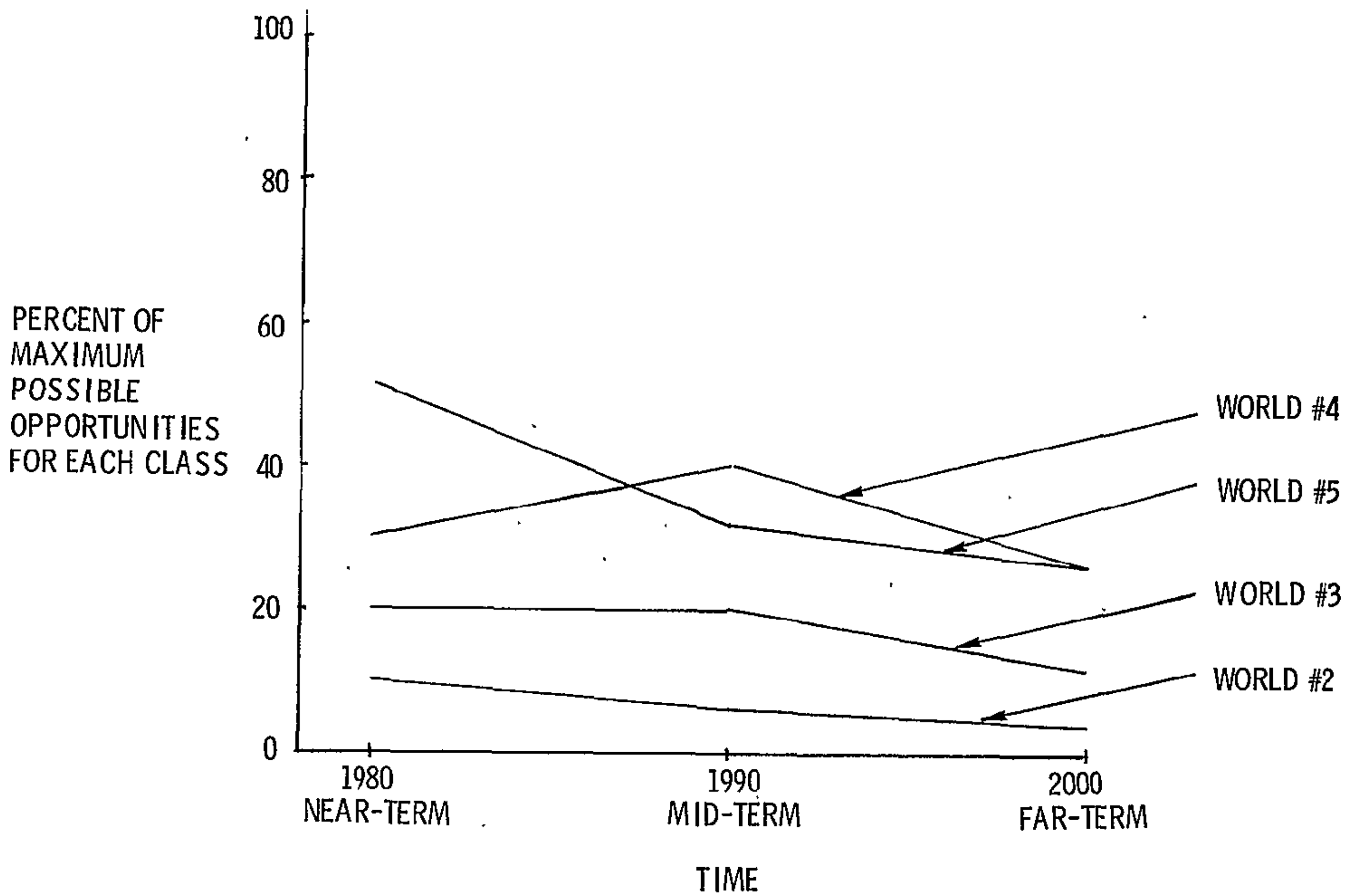
COMMON NEEDS FOR THE TUG



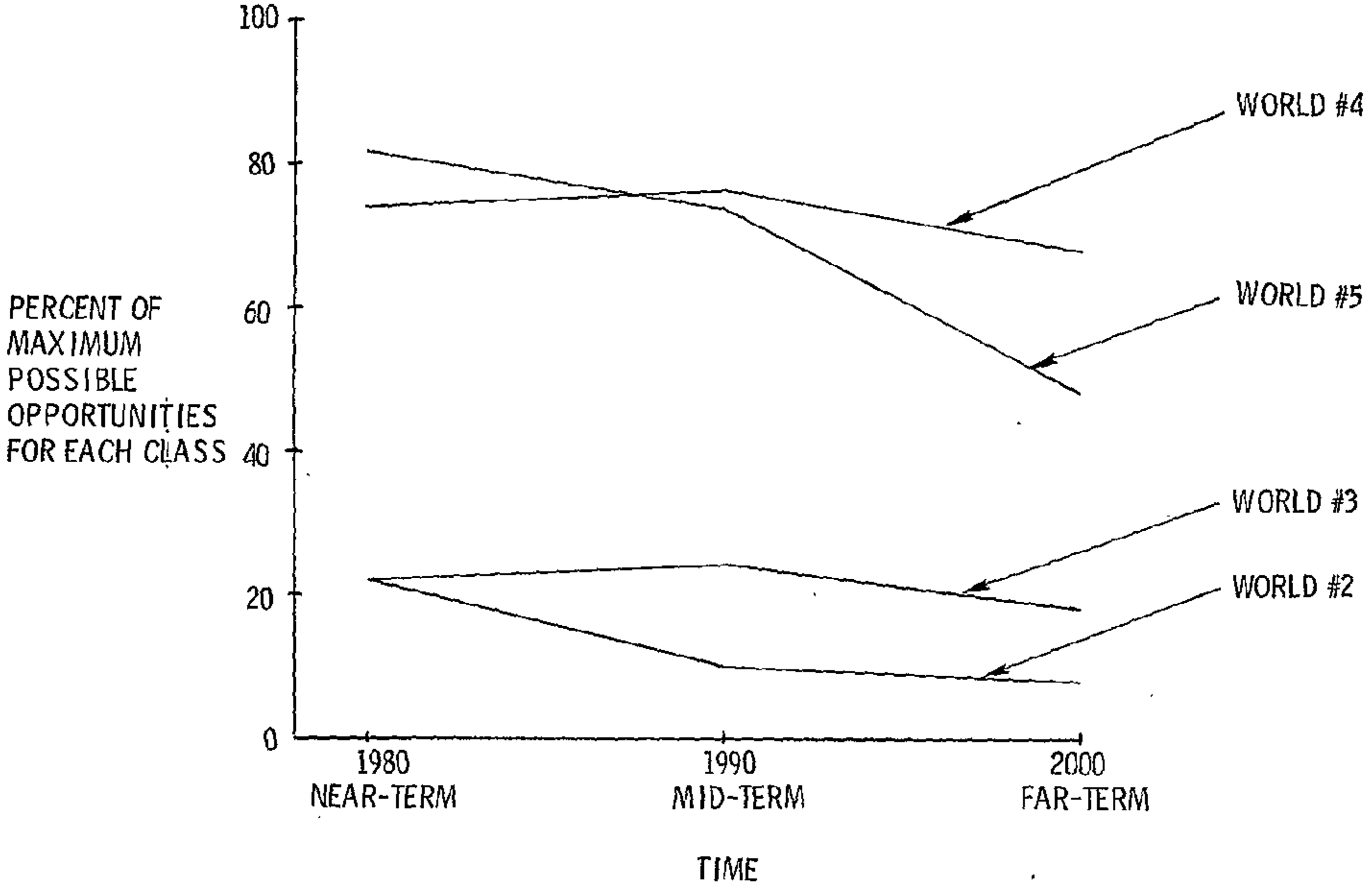
COMMON NEEDS FOR THE LARGE TUG



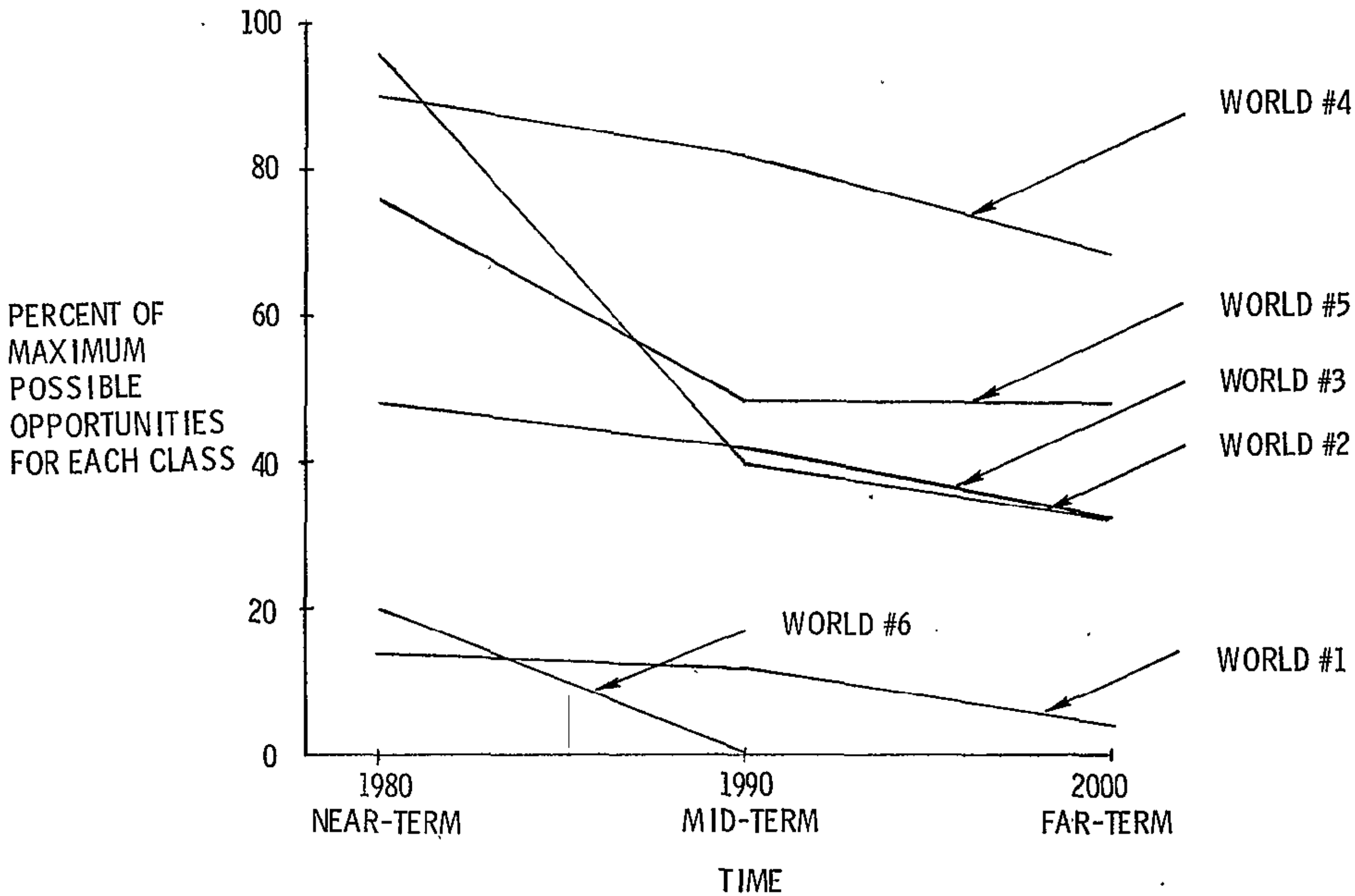
COMMON NEEDS FOR THE SEPS



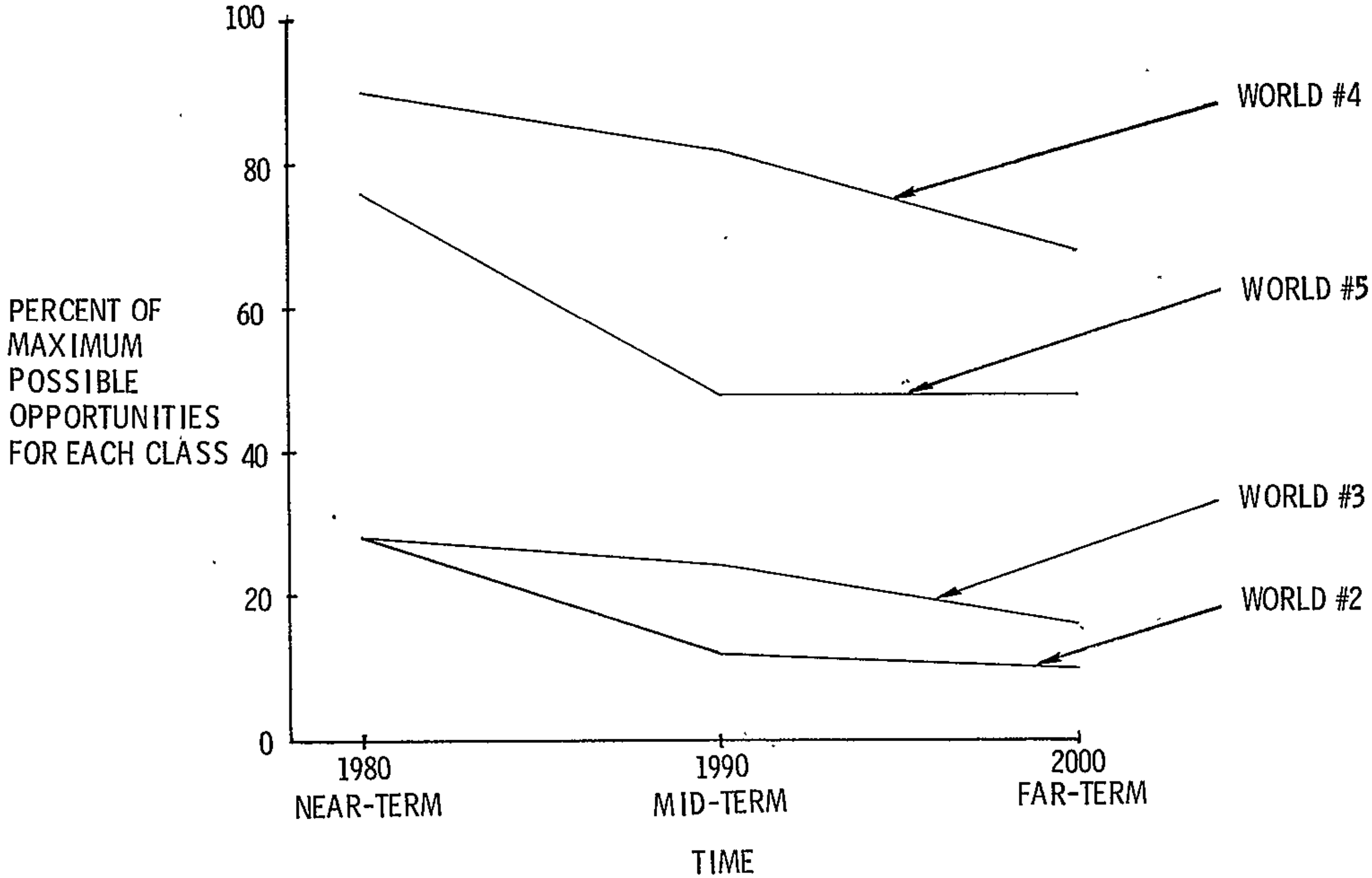
COMMON NEEDS FOR THE SHUTTLE ATTACHED MANIPULATOR



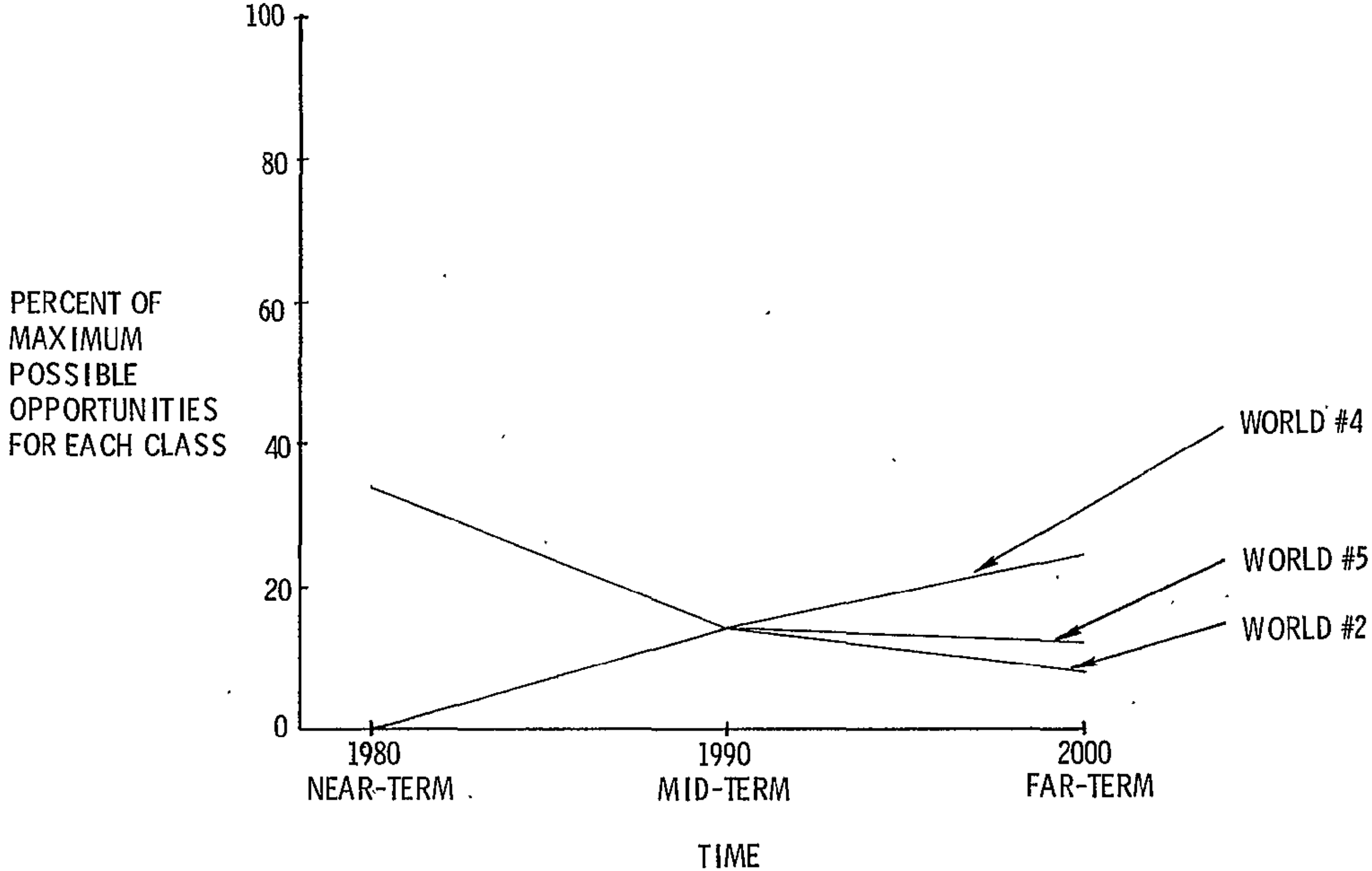
COMMON NEEDS FOR THE AUTOMATED SERVICING UNIT



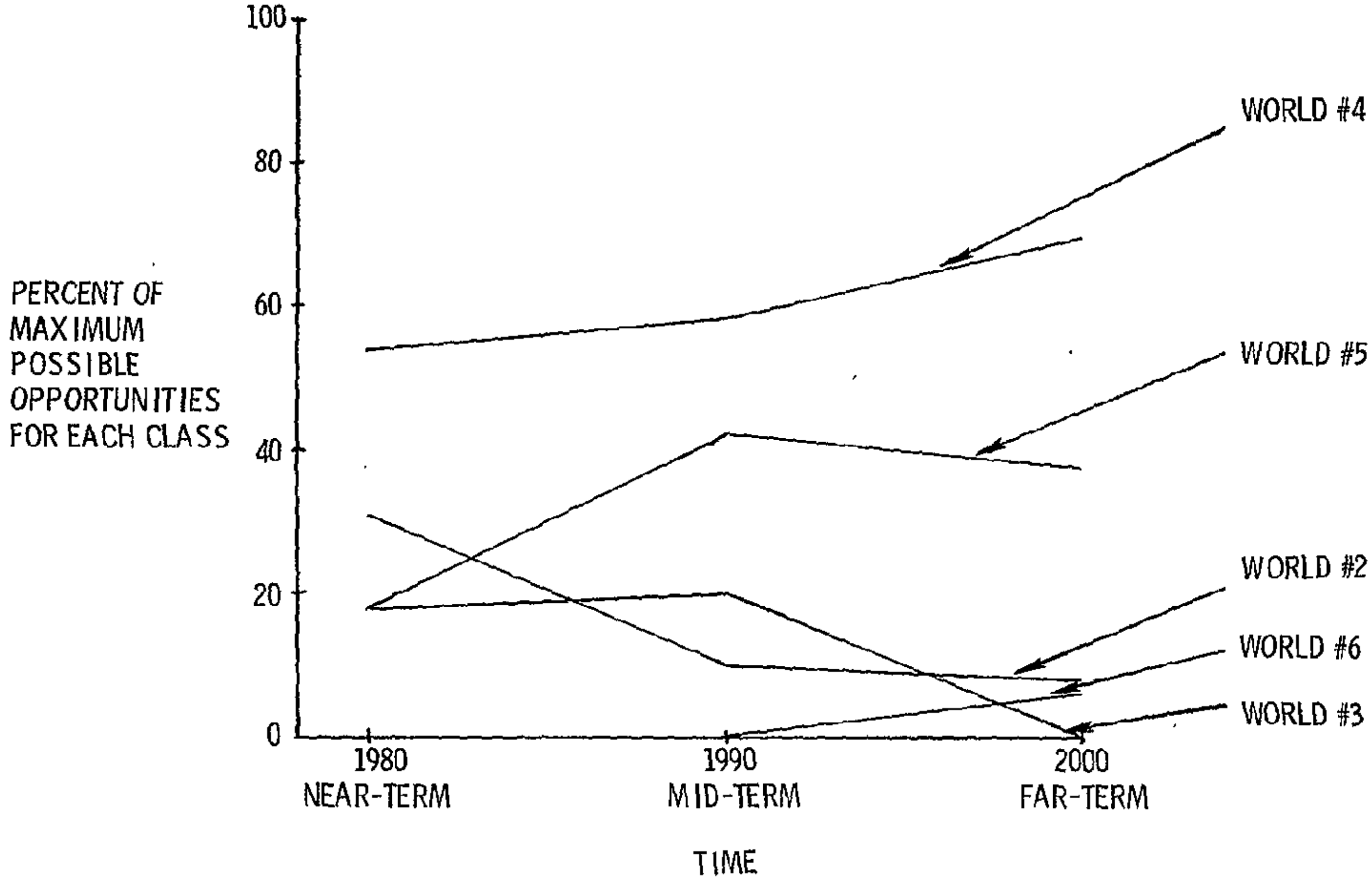
COMMON NEEDS FOR THE MANNED SERVICING UNIT



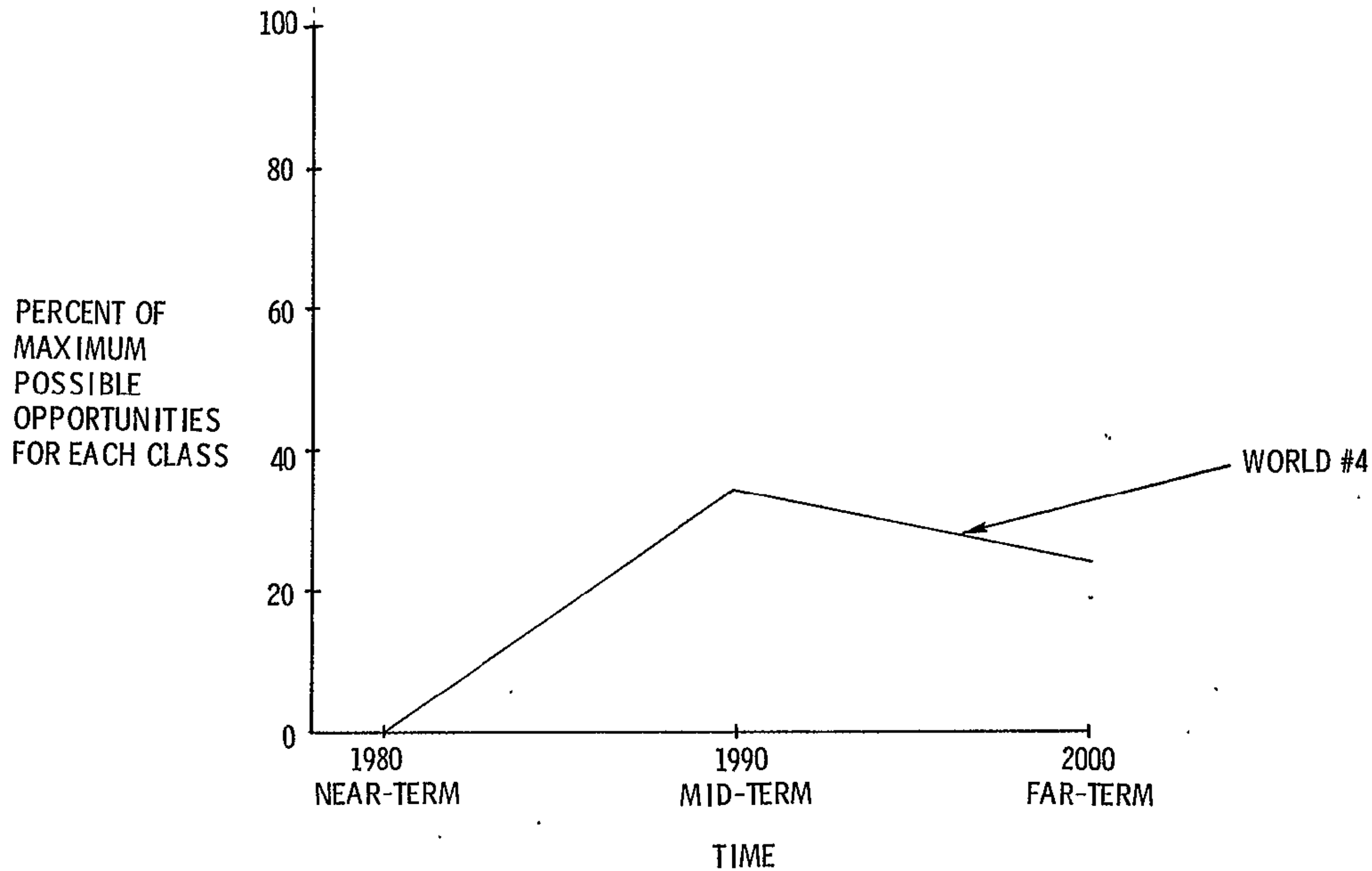
COMMON NEEDS FOR THE FREE-FLYING TELEOPERATOR



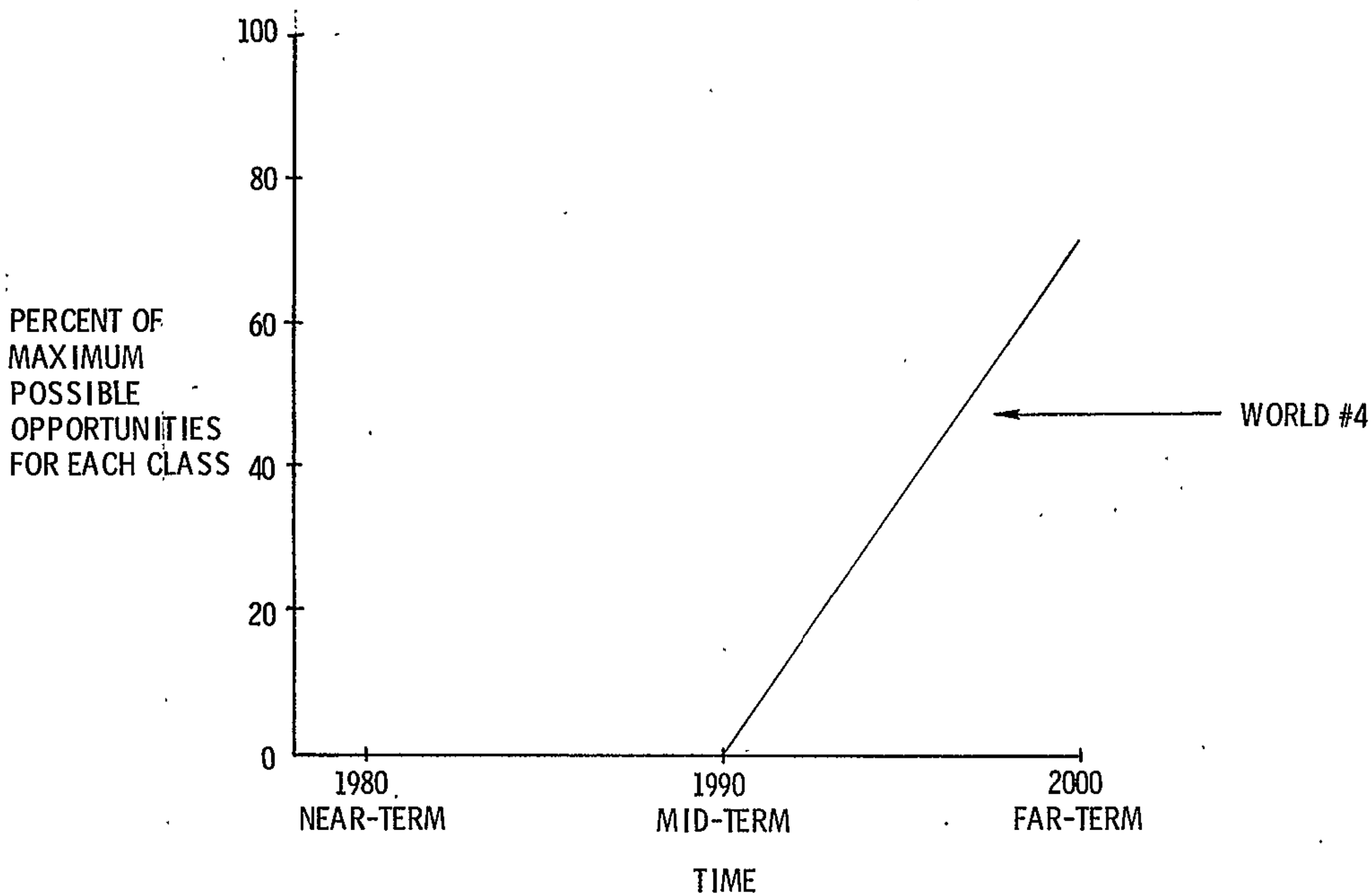
COMMON NEEDS FOR THE ORBITAL ASSEMBLY AND MAINTENANCE FACILITY

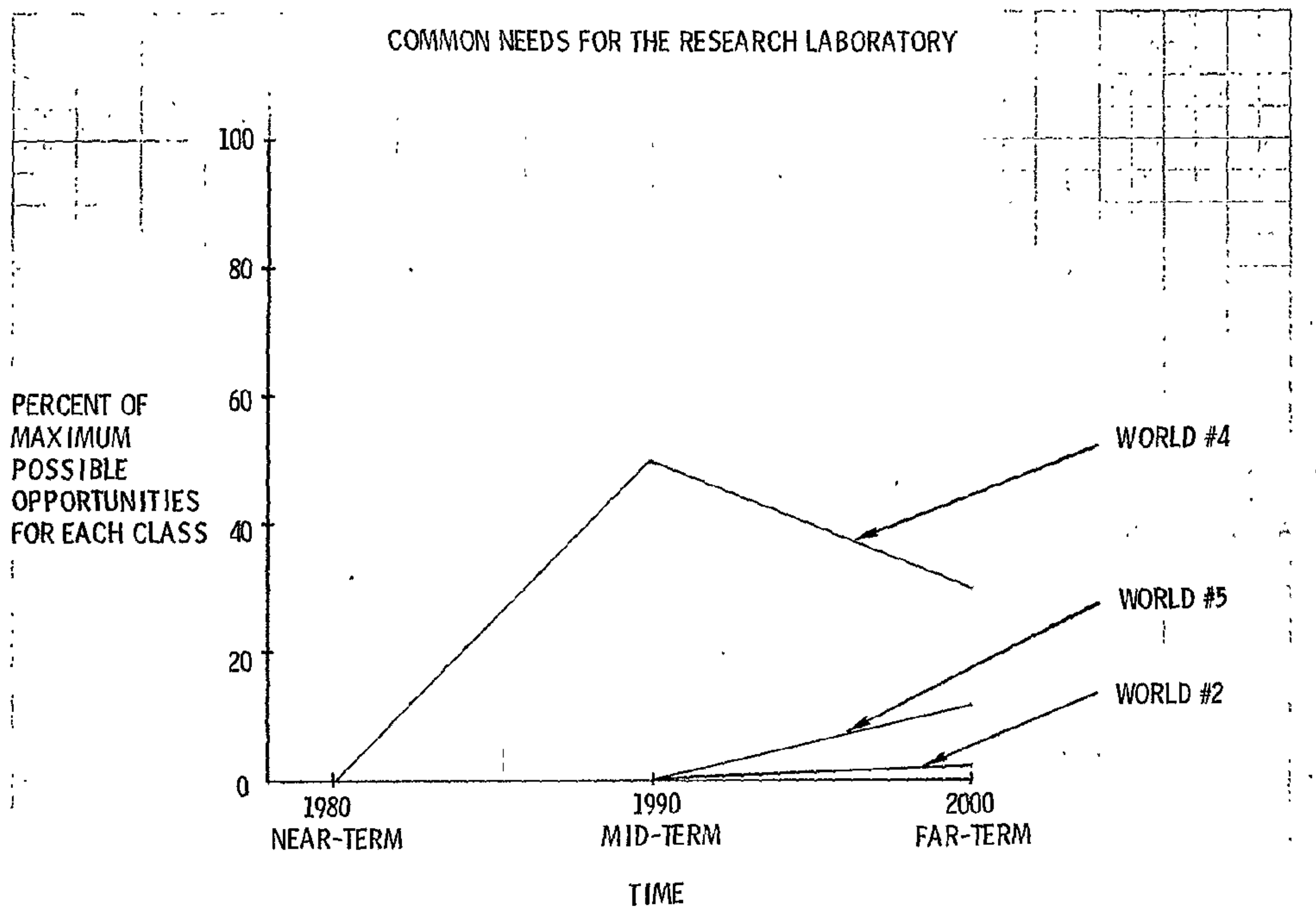


COMMON NEEDS FOR THE ORBITAL WAREHOUSE

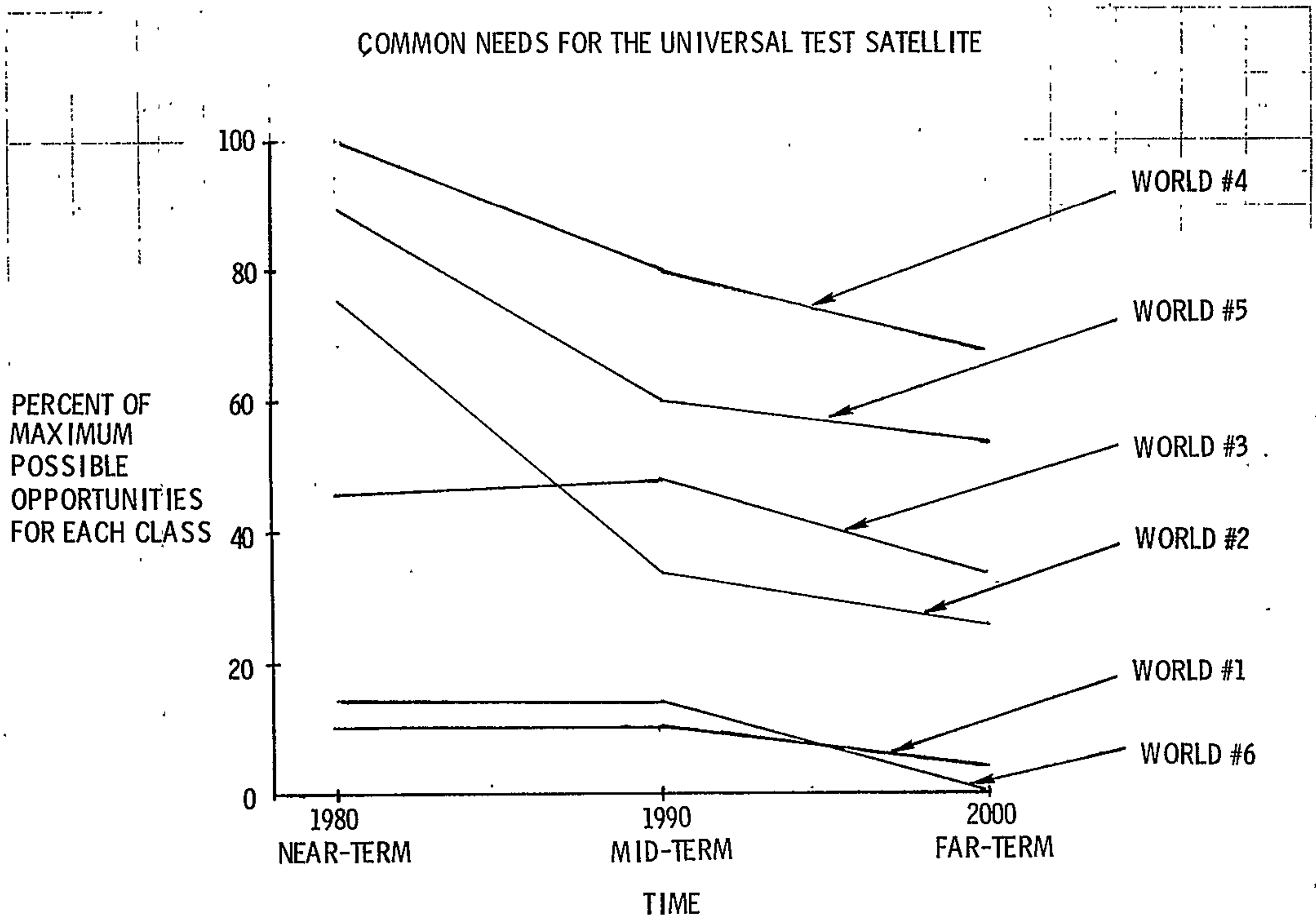


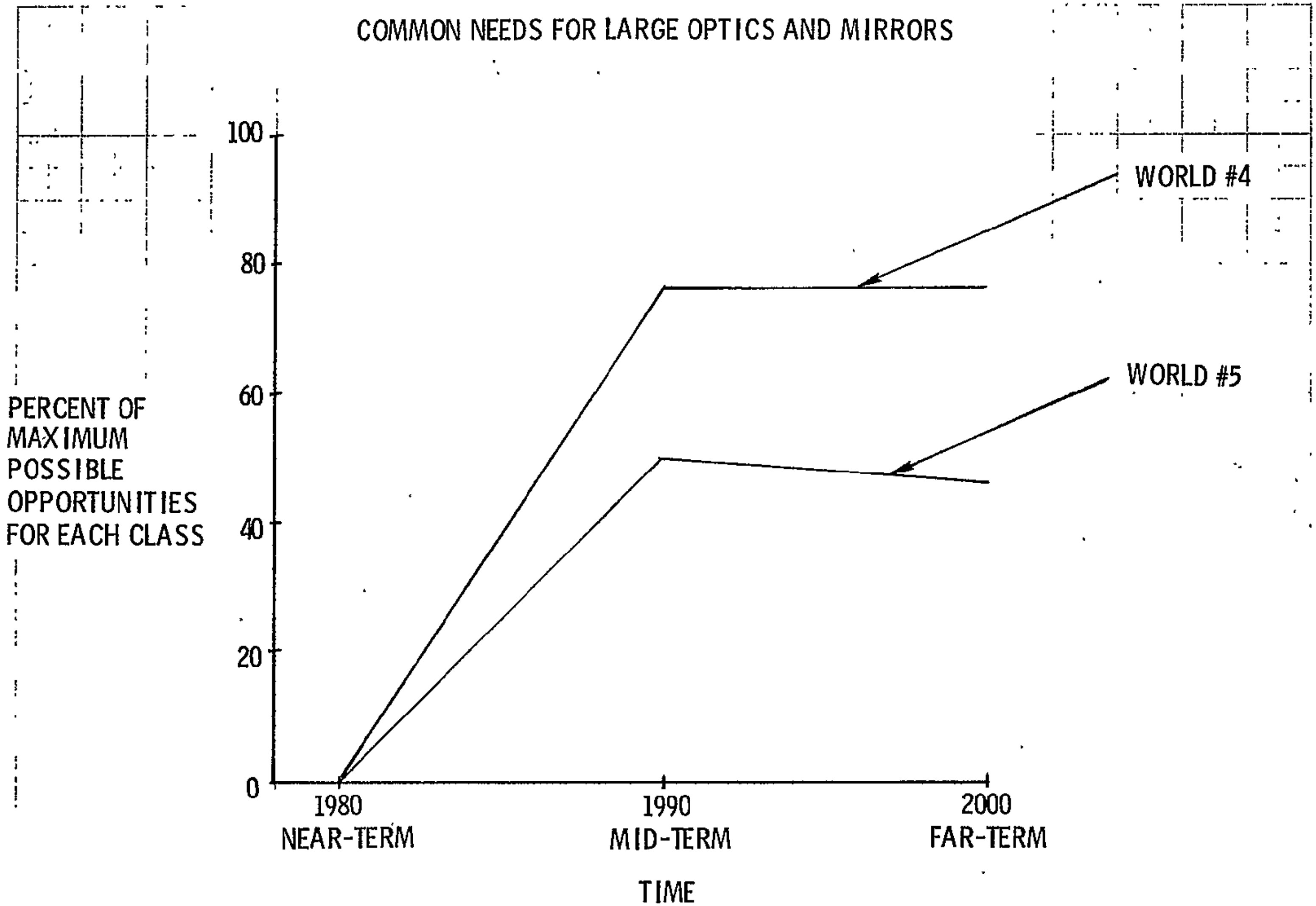
COMMON NEEDS FOR THE ORBITAL FABRICATION FACILITY

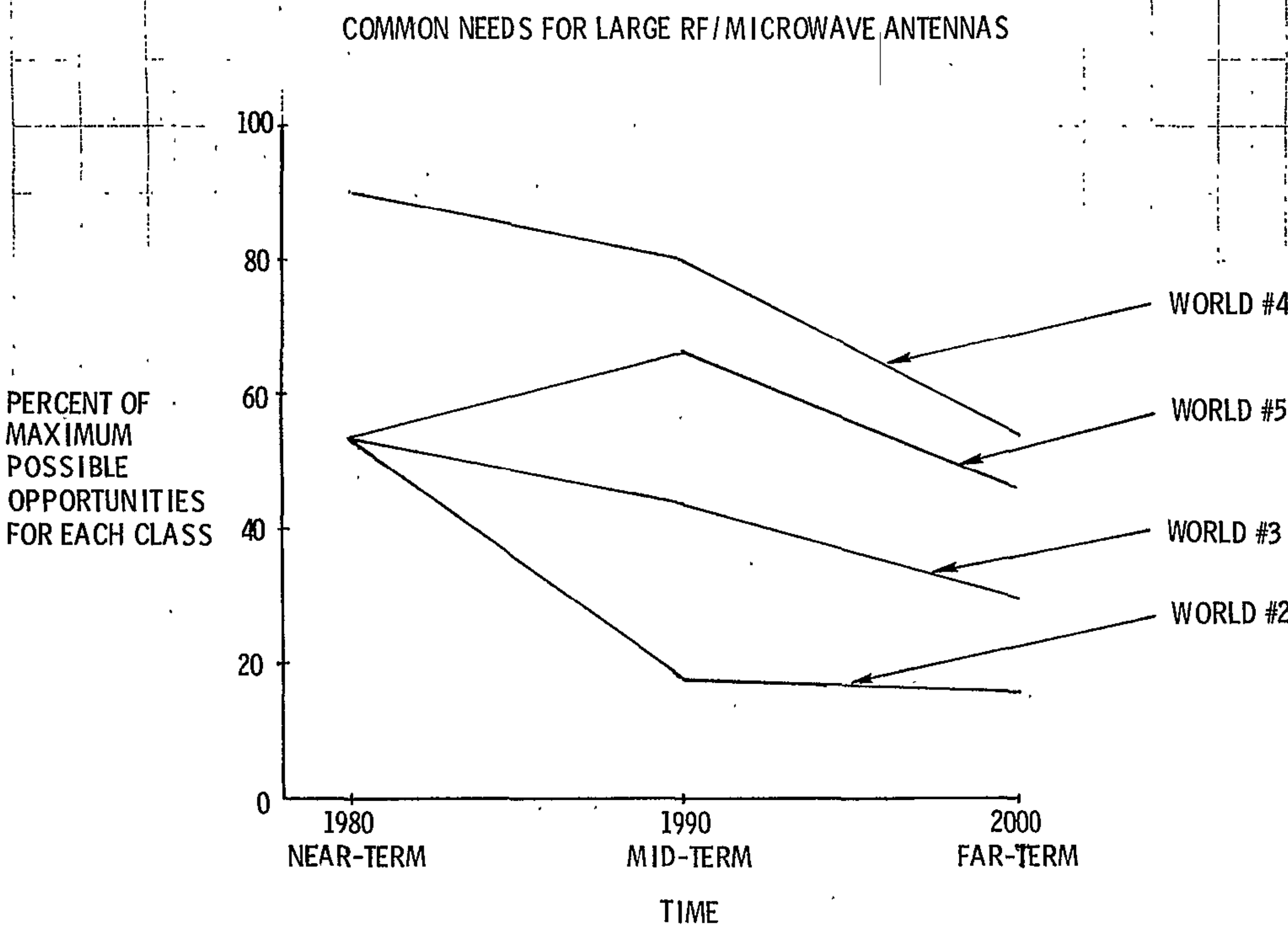


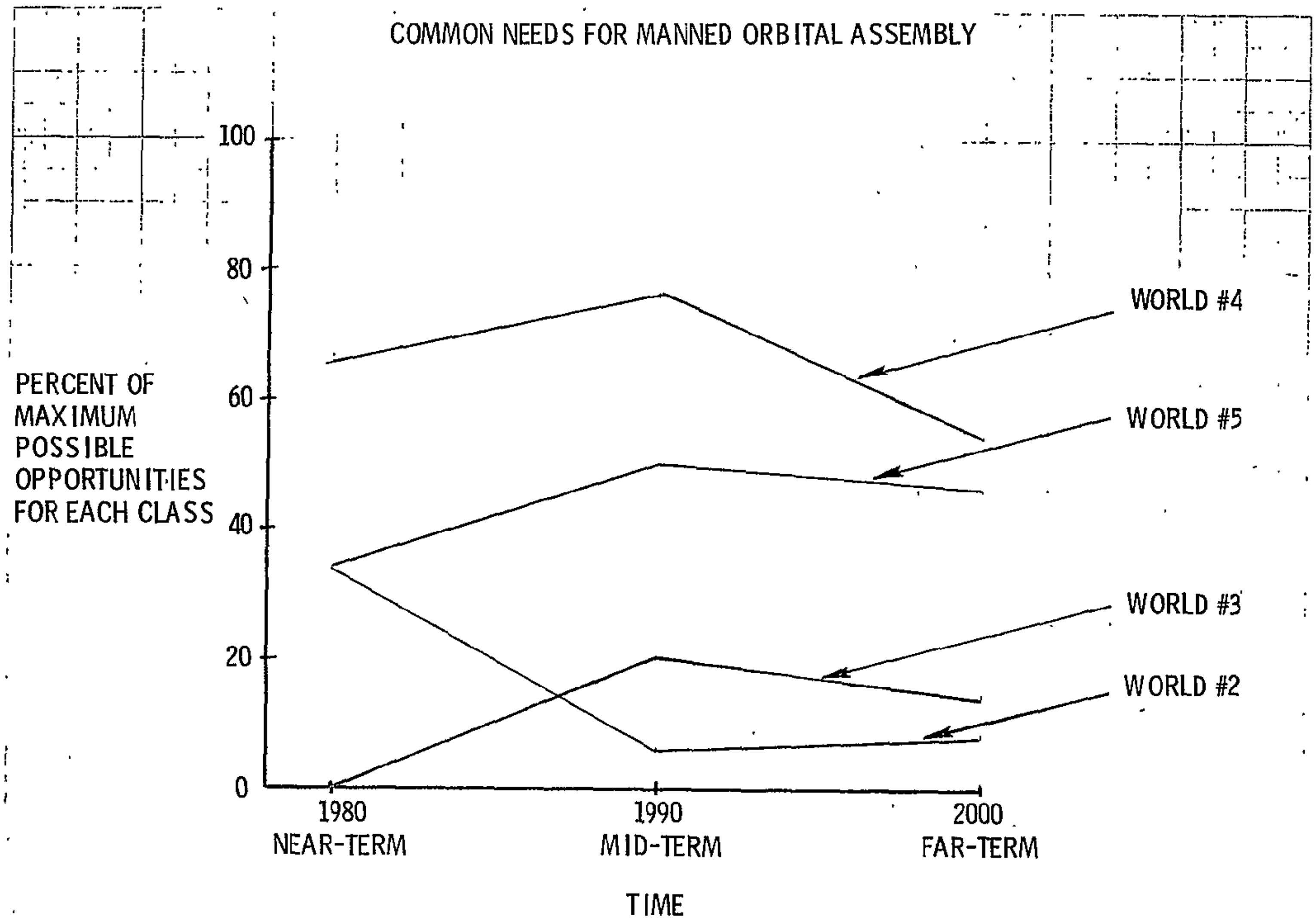


COMMON NEEDS FOR THE RESEARCH LABORATORY
PERCENT OF
MAXIMUM
POSSIBLE
OPPORTUNITIES
FOR EACH CLASS
100
80
60
40
20
0
1980
NEAR-TERM
1990
MID-TERM
2000
FAR-TERM
TIME
WORLD #4
WORLD #5
WORLD #2

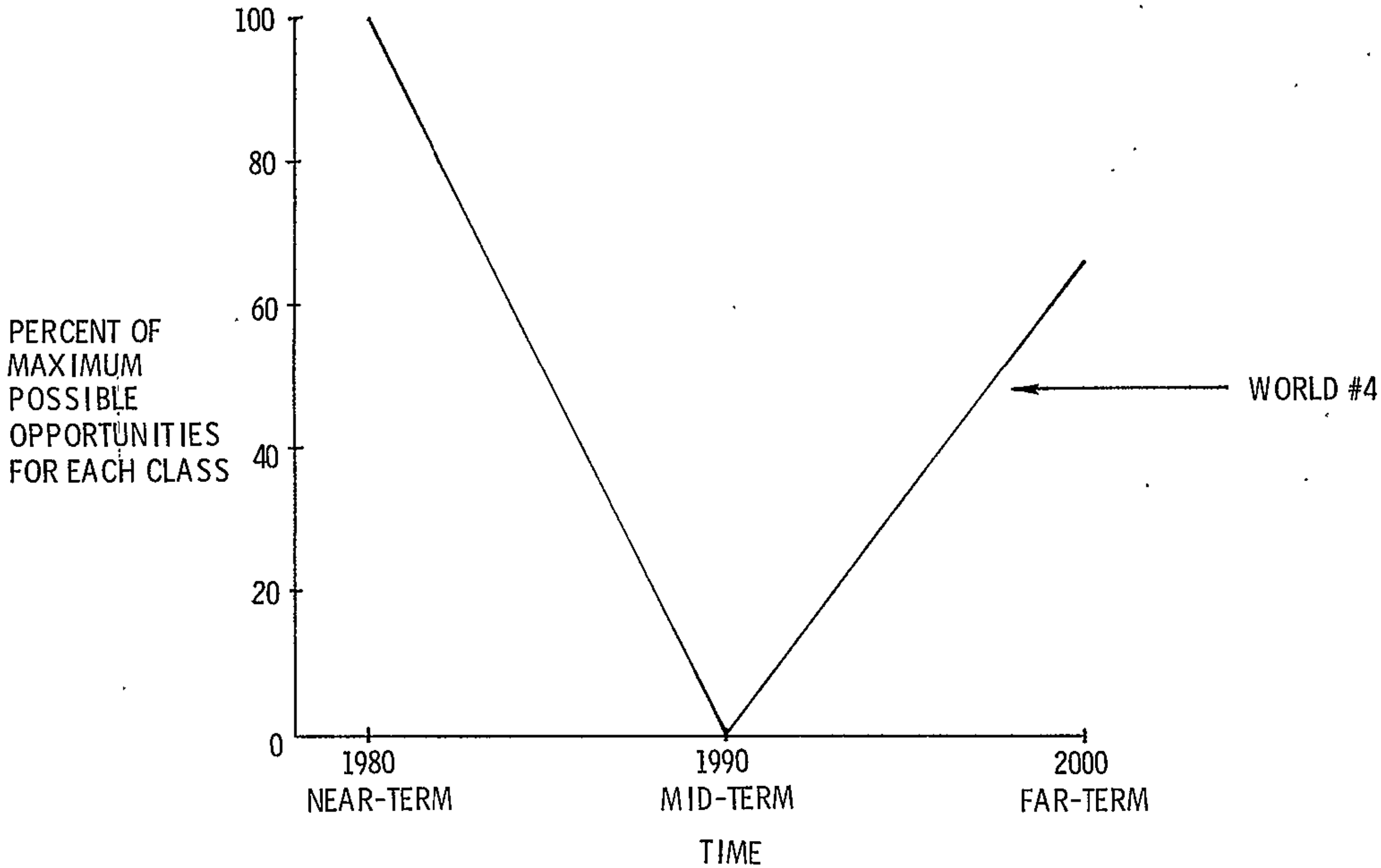

COMMON NEEDS FOR THE UNIVERSAL TEST SATELLITE
PERCENT OF MAXIMUM POSSIBLE OPPORTUNITIES FOR EACH CLASS
100
80
60
40
20
0
1980
NEAR-TERM
1990
MID-TERM
2000
FAR-TERM
TIME
WORLD #4
WORLD #5
WORLD #3
WORLD #2
WORLD #1
WORLD #6

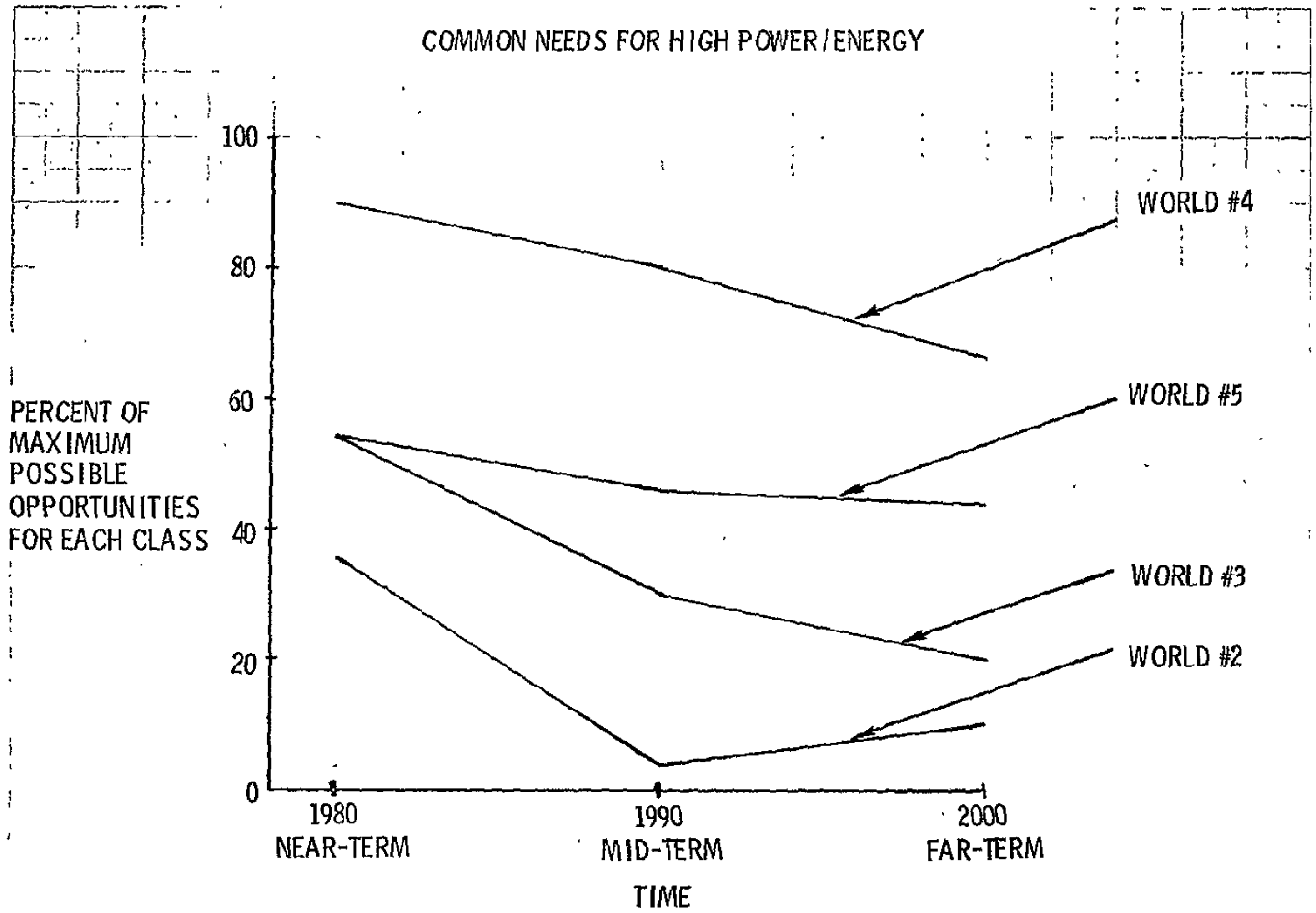

COMMON NEEDS FOR LARGE OPTICS AND MIRRORS
PERCENT OF MAXIMUM POSSIBLE OPPORTUNITIES FOR EACH CLASS
100
80
60
40
20
0
1980
NEAR-TERM
1990
MID-TERM
2000
FAR-TERM
TIME
WORLD #4
WORLD #5


COMMON NEEDS FOR LARGE RF/MICROWAVE ANTENNAS
PERCENT OF MAXIMUM POSSIBLE OPPORTUNITIES FOR EACH CLASS
100
80
60
40
20
0
1980
NEAR-TERM
1990
MID-TERM
2000
FAR-TERM
TIME
WORLD #4
WORLD #5
WORLD #3
WORLD #2

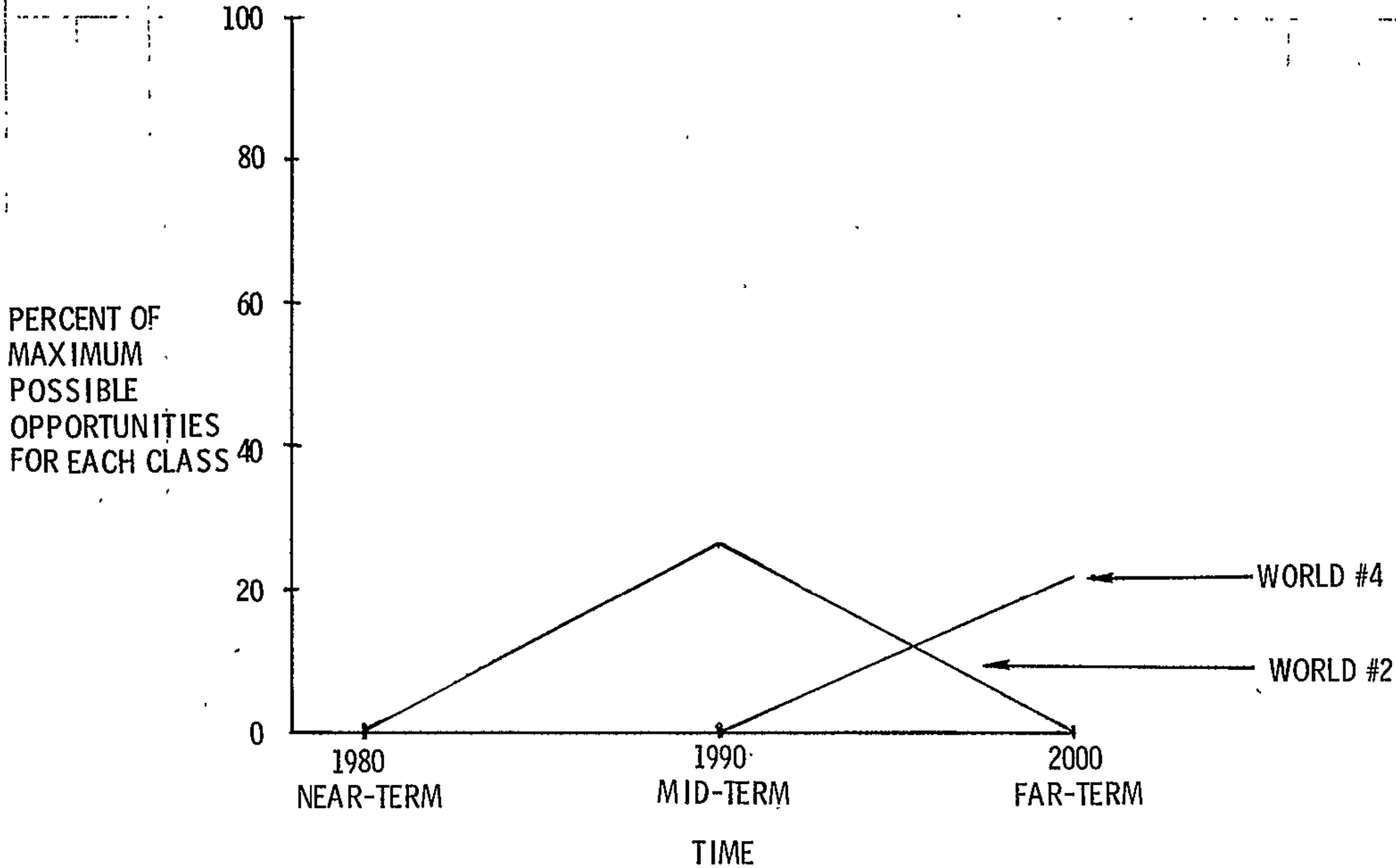

COMMON NEEDS FOR MANNED ORBITAL ASSEMBLY
PERCENT OF MAXIMUM POSSIBLE OPPORTUNITIES FOR EACH CLASS
100
80
60
40
20
0
WORLD #4
WORLD #5
WORLD #3
WORLD #2
1980
NEAR-TERM
1990
MID-TERM
2000
FAR-TERM
TIME

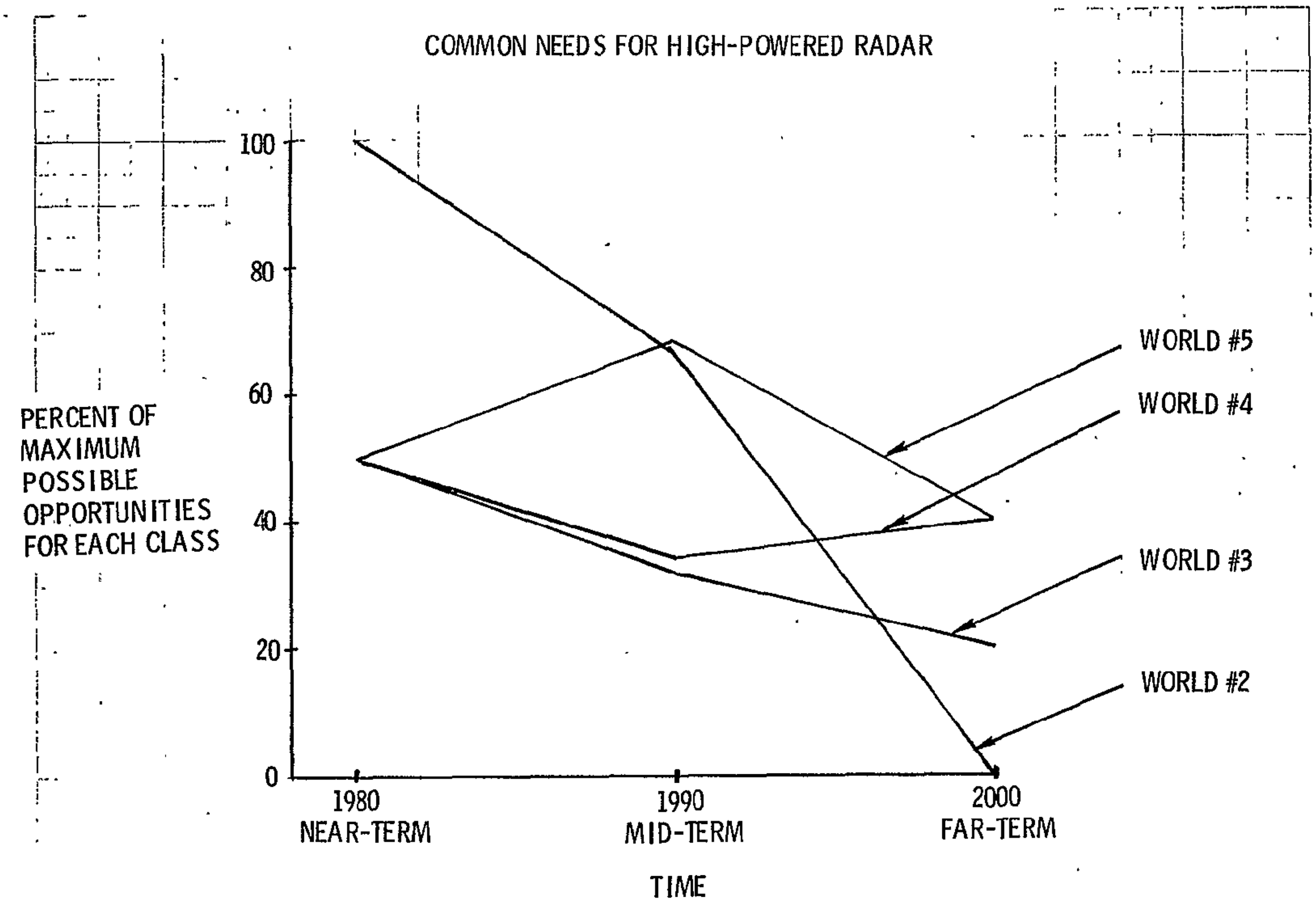
COMMON NEEDS FOR SPACE FABRICATION

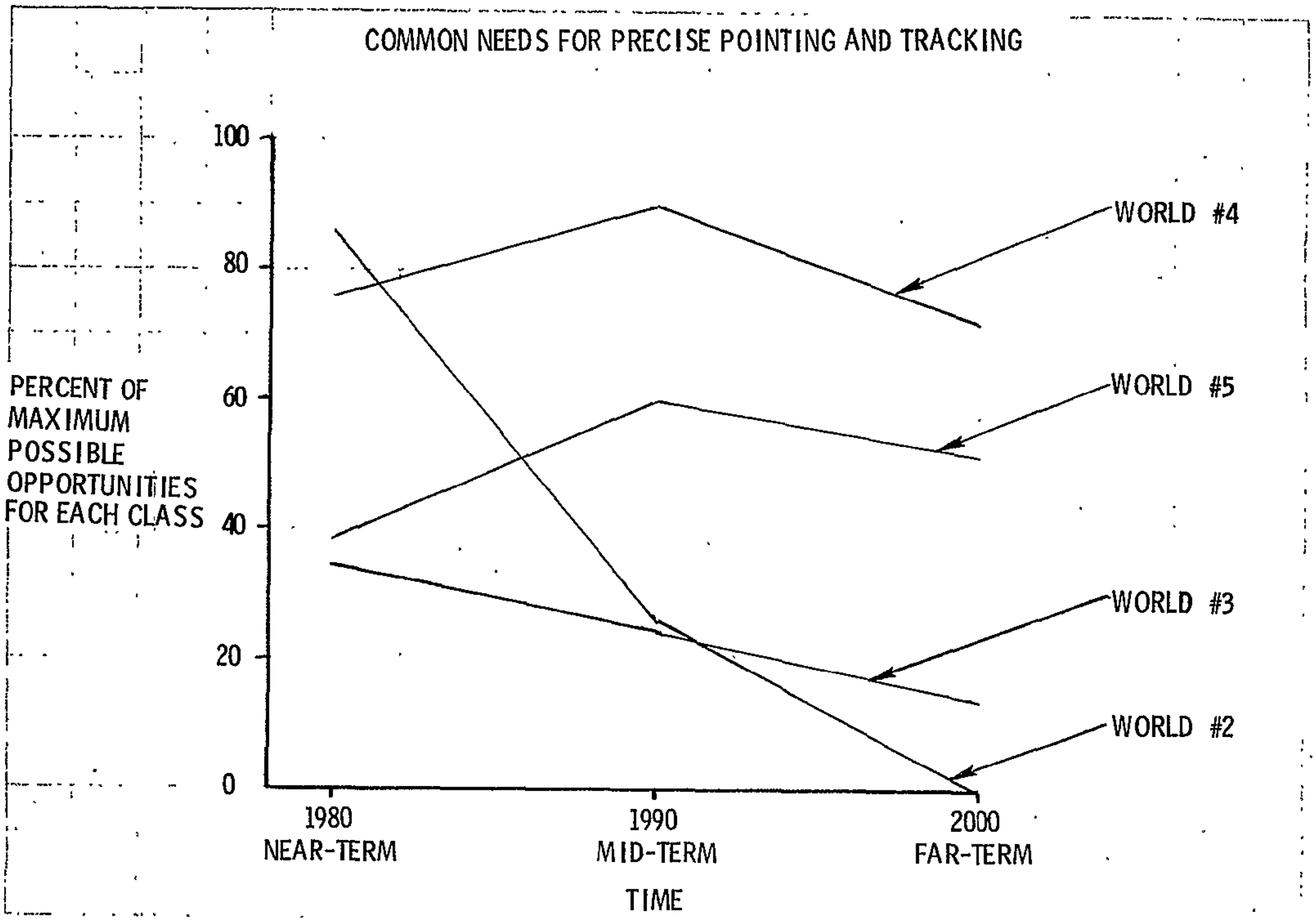


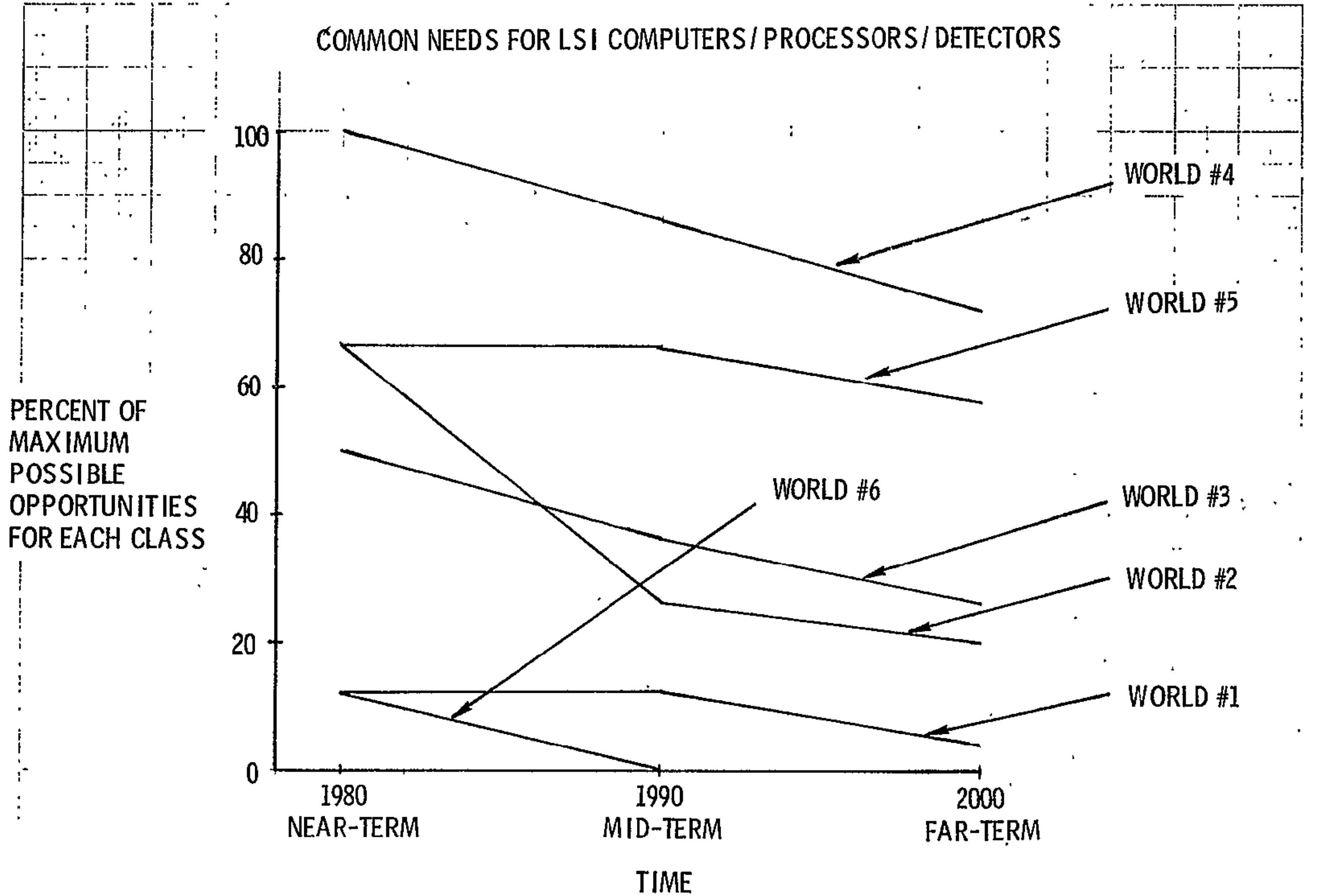

COMMON NEEDS FOR HIGH POWER/ENERGY
PERCENT OF MAXIMUM POSSIBLE OPPORTUNITIES FOR EACH CLASS
100
80
60
40
20
0
1980
NEAR-TERM
1990
MID-TERM
2000
FAR-TERM
TIME
WORLD #4
WORLD #5
WORLD #3
WORLD #2

COMMON NEEDS FOR HIGH ENERGY LASERS



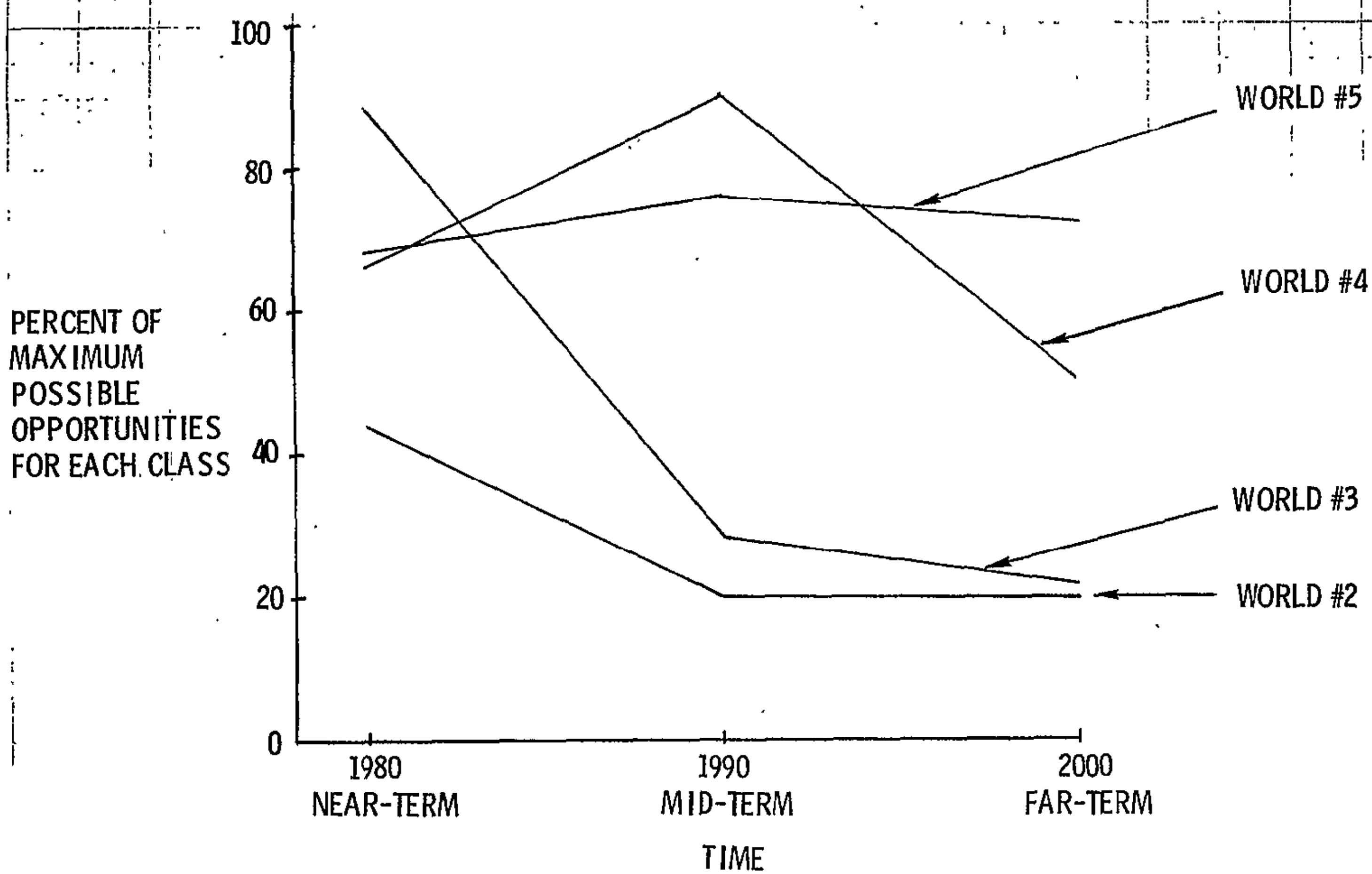

COMMON NEEDS FOR HIGH-POWERED RADAR
PERCENT OF MAXIMUM POSSIBLE OPPORTUNITIES FOR EACH CLASS
100
80
60
40
20
0
1980 NEAR-TERM
1990 MID-TERM
2000 FAR-TERM
TIME
WORLD #5
WORLD #4
WORLD #3
WORLD #2

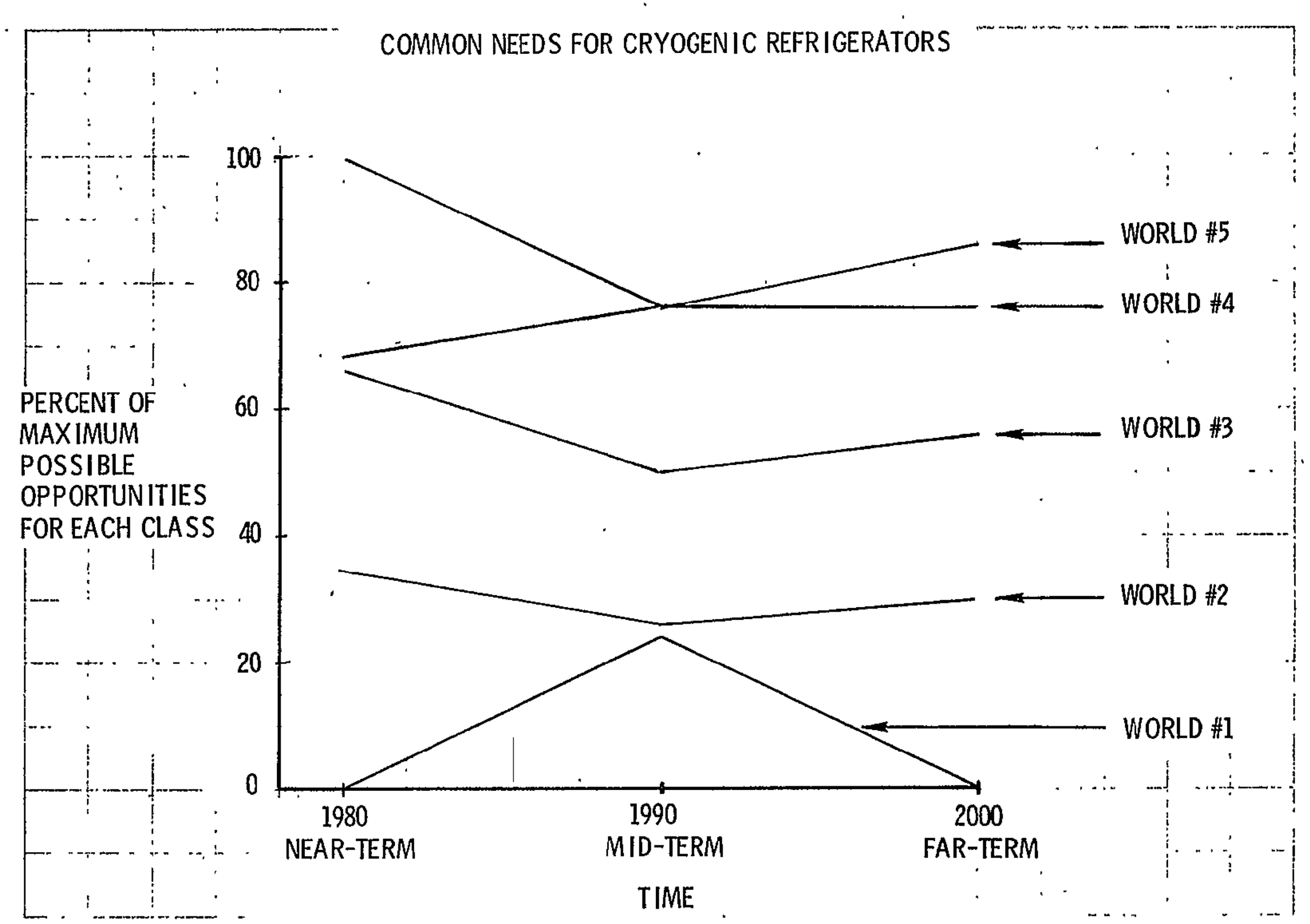

COMMON NEEDS FOR PRECISE POINTING AND TRACKING
PERCENT OF MAXIMUM POSSIBLE OPPORTUNITIES FOR EACH CLASS
100
80
60
40
20
0
WORLD #4
WORLD #5
WORLD #3
WORLD #2
1980
NEAR-TERM
1990
MID-TERM
2000
FAR-TERM
TIME



COMMON NEEDS FOR LSI COMPUTERS/PROCESSORS/DETECTORS
PERCENT OF MAXIMUM POSSIBLE OPPORTUNITIES FOR EACH CLASS
100
80
60
40
20
0
1980
NEAR-TERM
1990
MID-TERM
2000
FAR-TERM
TIME
WORLD #4
WORLD #5
WORLD #6
WORLD #3
WORLD #2
WORLD #1

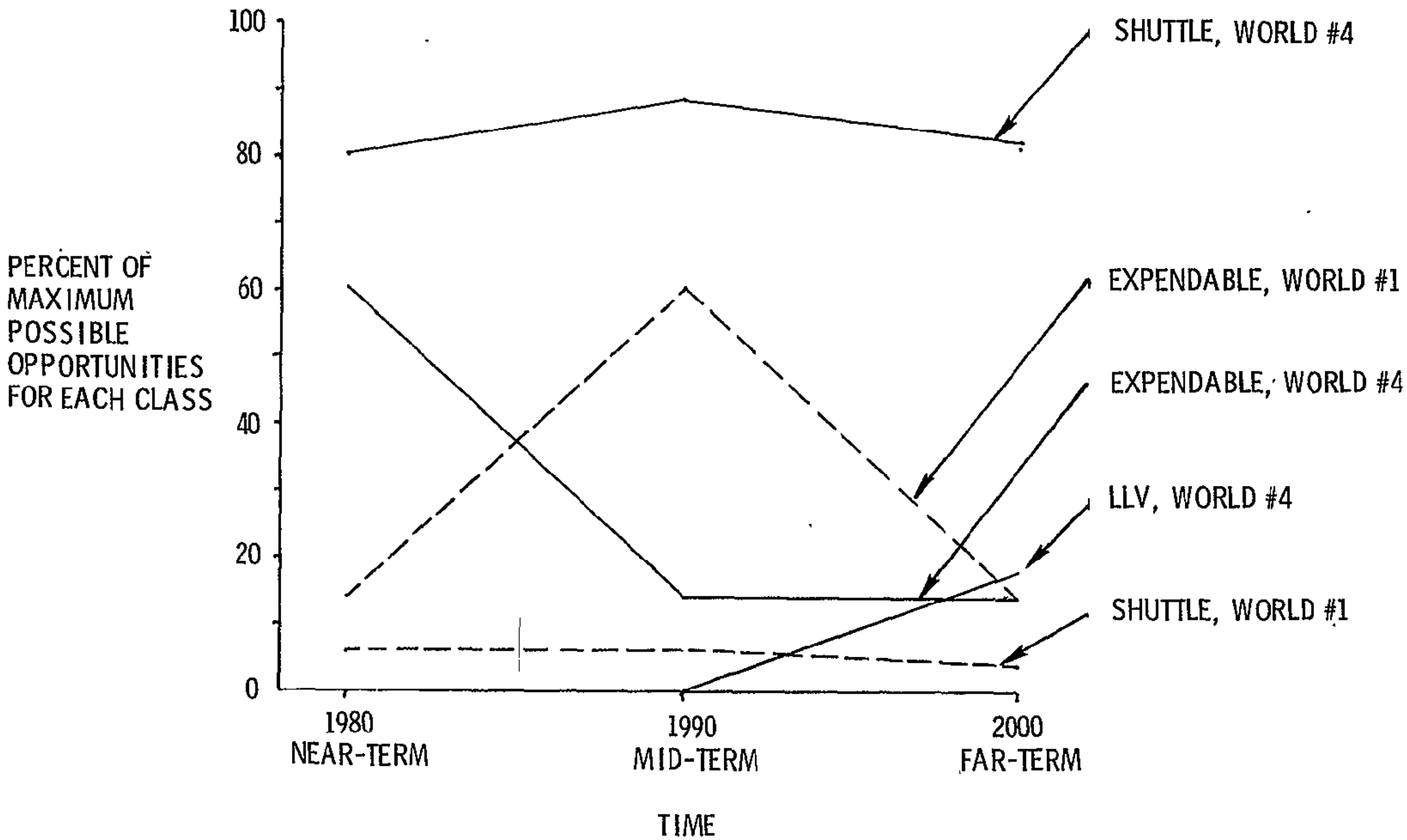
COMMON NEEDS FOR MOSAIC/CCD FOCAL PLANES



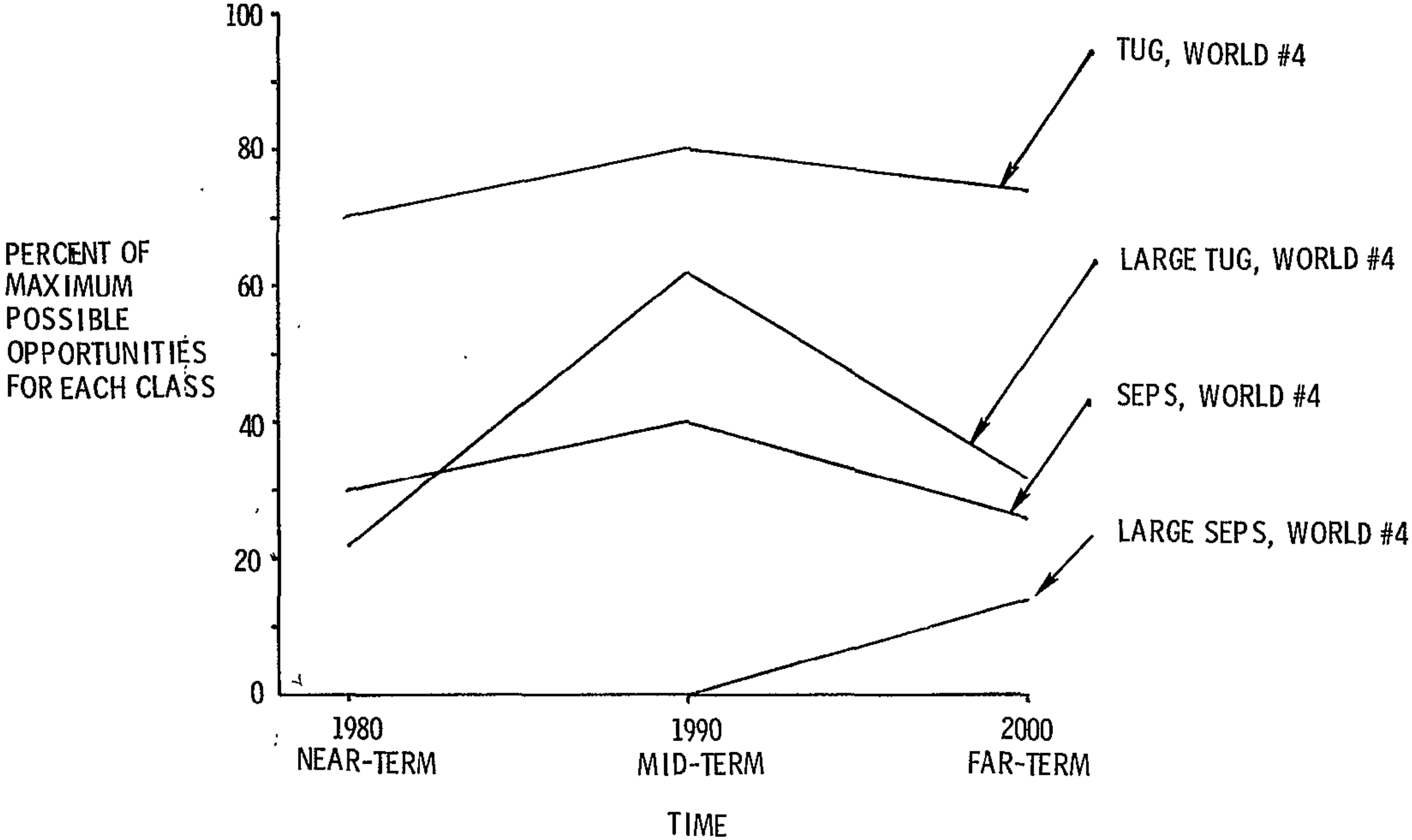

COMMON NEEDS FOR CRYOGENIC REFRIGERATORS
PERCENT OF MAXIMUM POSSIBLE OPPORTUNITIES FOR EACH CLASS
100
80
60
40
20
0
1980
NEAR-TERM
1990
MID-TERM
2000
FAR-TERM
TIME
WORLD #5
WORLD #4
WORLD #3
WORLD #2
WORLD #1

The following graphs show the common needs for the building blocks and technologies for Worlds #1 and #4 as a function of time. The intent here is to present a complete building block or technology category on a single chart.

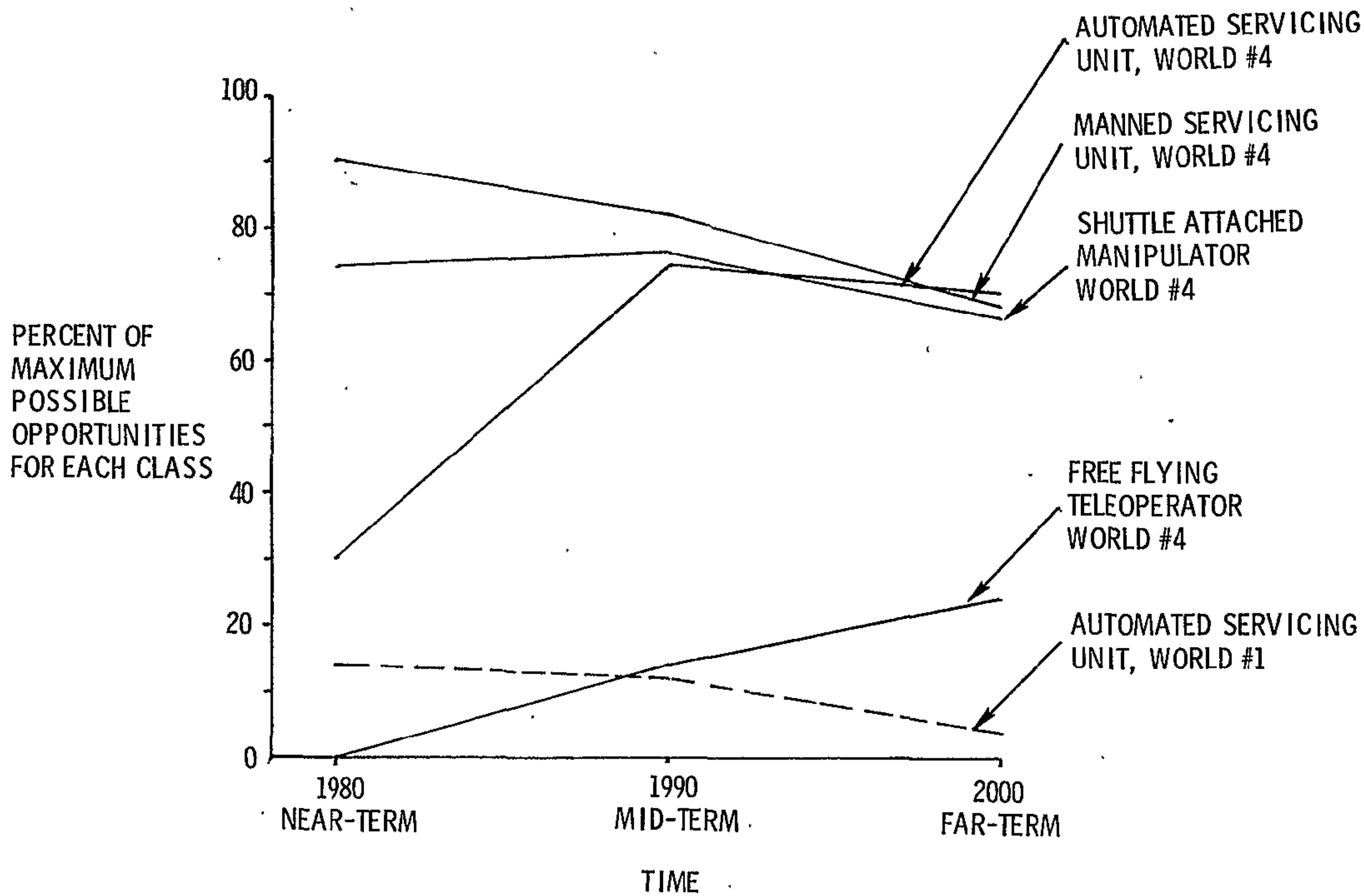
COMMON NEEDS FOR LOW EARTH ORBIT TRANSPORTATION



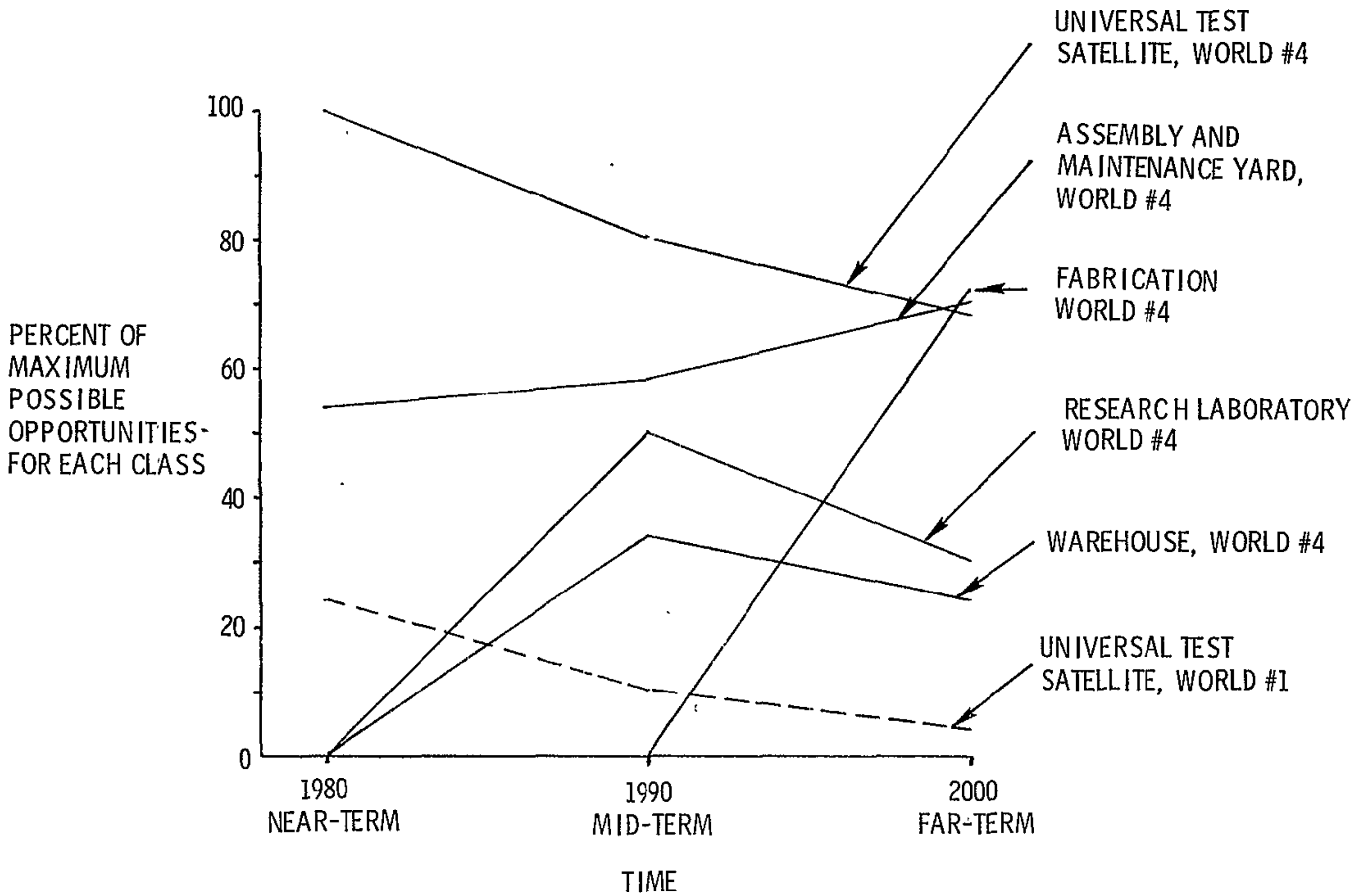
COMMON NEEDS FOR HIGH ORBIT/TRANSFER TRANSPORTATION



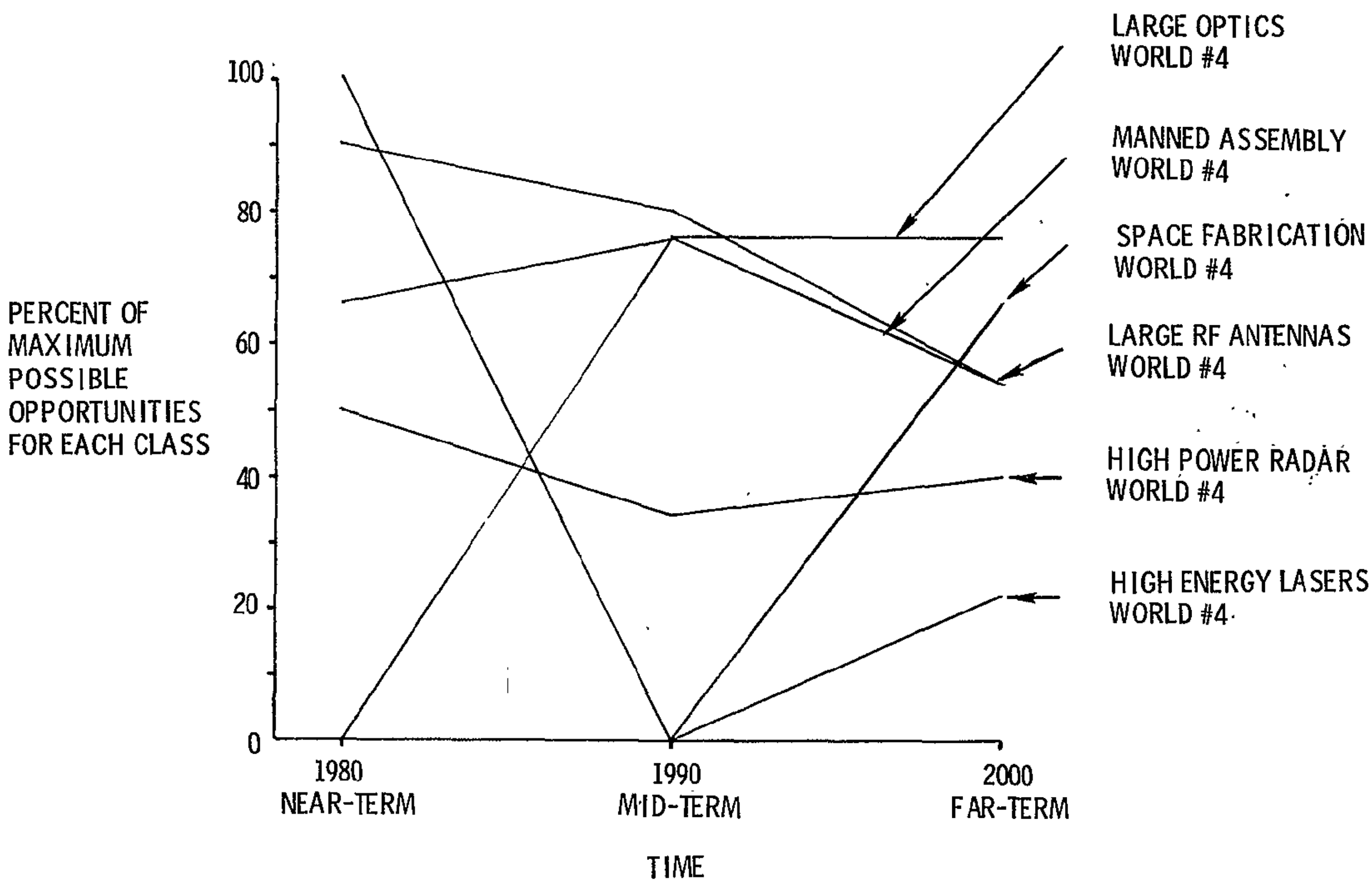
COMMON NEEDS FOR ORBITAL ASSEMBLY AND SERVICING STAGES



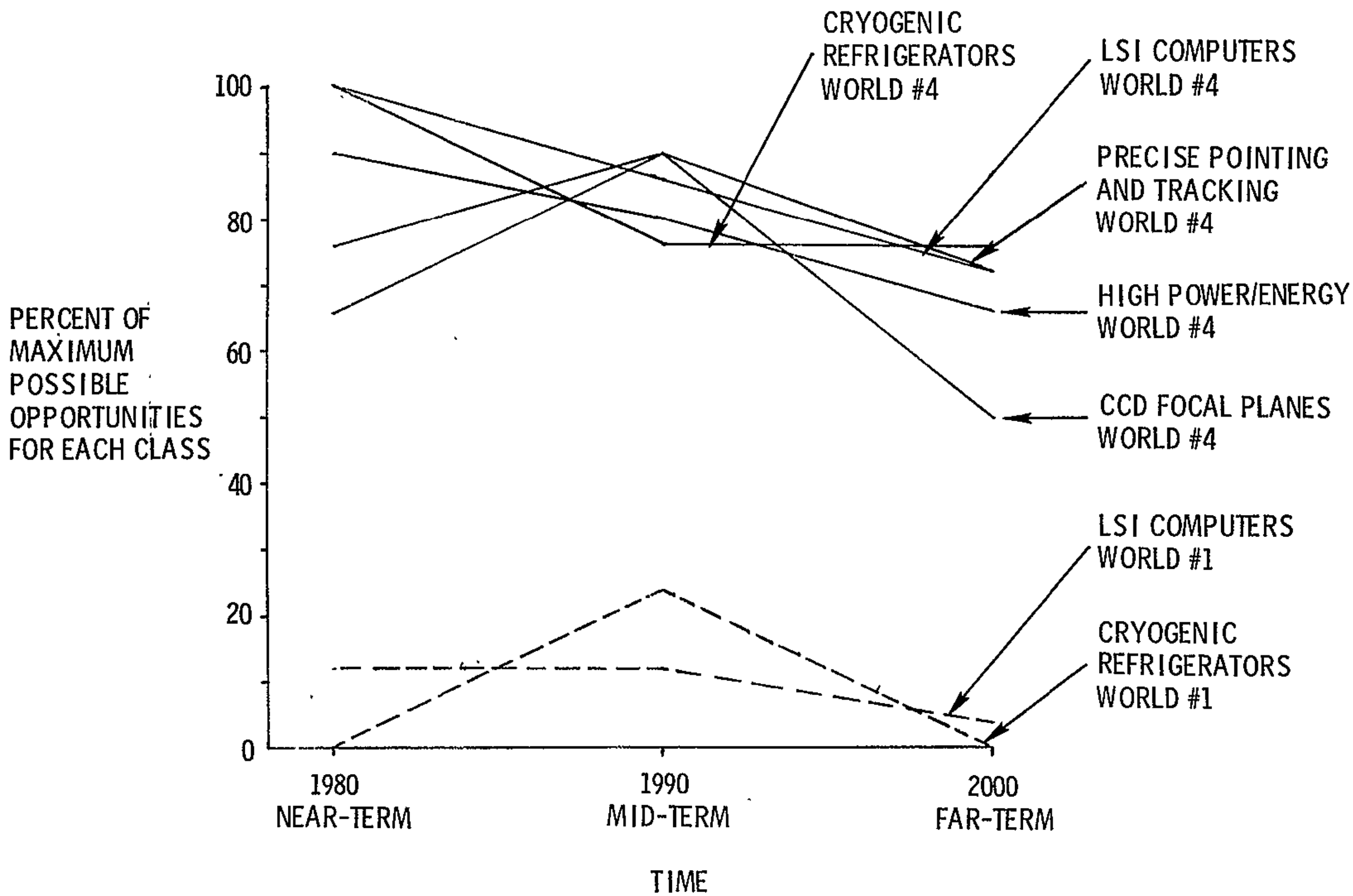
COMMON NEEDS FOR ORBITAL SUPPORT FACILITIES



COMMON NEEDS FOR ORBITAL TECHNIQUES AND TECHNOLOGY



COMMON NEEDS FOR ORBITAL TECHNIQUES AND TECHNOLOGY



APPENDIX A

A METHODOLOGY FOR EVALUATING THE MERITS OF ALTERNATIVE PROGRAM PLANS

BY

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Consulting Engineer

Prepared for

Advanced Orbital Systems Division

THE AEROSPACE CORPORATION

27 June 1975

El Segundo, California 90245

FOREWORD

The work discussed in this appendix was conducted by Dr. G. V. Nolde for the Advanced Orbital Systems Division of The Aerospace Corporation in support of NASA Study 2.5, "Study of the Commonality of Space Vehicle Applications to Future National Needs." Since the text is self-contained, it is presented as an appendix to the study, though the effort was performed in close coordination with the material comprising the body of the study.

A1. PLANNING METHODS, CRITERIA, AND EVALUATION ALGORITHM

The methodology described in this text is to be considered as an adjunct to the planning methodology described in the main text of this volume. It is intended for evaluation of the merits of particular space system initiatives or program plans (groups of initiatives in time-phased organization) when they progress further toward the project definition stage than the present status of most initiatives identified in the main text.

A1.1. NATIONAL OBJECTIVES

The term "National Objectives" is to be understood to be equivalent to "National Goals" as used in the main text. The task at hand requires identification of several sets of national objectives, followed by determination of several sets of program plans (group of initiatives), each derived for one particular set of national objectives.

The sets of national objectives to be adopted for this study must be chosen to be responsive to both internal and international circumstances or environments. This is particularly true of objectives which pertain to allocation of resources to civilian vs. military activities, which are treated in this study with particular emphasis on those activities affecting space utilization.

The methodology of this appendix depends on the identification of alternate sets of national objectives, which are described in the main text of this volume and are contained in the section on Alternate Future World Scenarios. In that section, a spectrum of international environments varying from balance to nuclear confrontation is combined with various internal environments to form at least six alternate sets of resultant national objectives. Those objectives are further described and defined in the sections of directives to the executive and planning organizations of the military and civilian agencies. This appendix will draw on those sections of the test.

A1.2. STATEMENT OF THE PROBLEM

The desired end results of this appendix are procedures suited for the evaluation of each space system initiative or groups of initiatives (program plans) and their supporting building blocks required. In the course of deriving the method for generation of such procedures, it will be assumed that no forecasts are to be made of the probability of occurrence of any set of international or domestic circumstances or environment.

In order to proceed toward the above goal, a list should be prepared of the features of the U.S. National Objectives derived. Each feature is to be analytically broken down into one or more factors,. each of which must be capable of being abstracted to serve as a part of a generator for a procedure of comparison or evaluation of the space system initiatives or their building blocks.

The suitable characteristics of the initiatives are to be appropriately selected and listed. Each of these characteristics are to be capable of serving as a complementary part of the comparison generator mentioned above.

On completion of the items above, a list should be prepared of the definitions of effectiveness resulting from consideration of the initiatives, groups of initiatives, or building blocks as a function of the national goals selected for illustration. The definitions of effectiveness are to be examined to see if they can be grouped to advantage.

Next, proceed to evolve operations, operands, and figure-of-merit algorithms on other advantageous measures of effectiveness. Note the usage of terms: definition of effectiveness is a different entity from its measure.

Finally, perform an example of computations to obtain the operational resultant outlined above.

A1.3. ORGANIZATION OF OPERATIONS-RESEARCH

The work on forecasting the most likely set (or sets) of National Objectives to be expected in the midrange of the present long-range study

(about 1990) will have to be completed for determining the concrete magnitudes of the factors identified in this appendix. The methodology discussed below has the character of a parametric estimate.

An organization of the planning procedure developed follows:

a. <u>Operation</u>

1. Design engineering of the given initiatives or one of its components
2. Test and evaluation
3. Production engineering
4. Prototype production
5. Delivery to launch facility
6. Assembly on launch vehicles
7. Launch and deployment in space
8. Refurbishing of launch vehicles

1S. Fabrication of operation systems

2S. Test and evaluation

3S. Delivery to launch facilities

4S. Launch and deployment

5S. Refurbishing of launch vehicles

6S. Maintenance and resupply for T_{MS} years period.

b. <u>Effectiveness</u> - Factors delineated in one of the columns of rows 4 and 5, Table A1-1.

c. <u>Symbolic Operators</u> - Factors delineated in one of the columns of rows 6 and 7, Table A1-1.

d. <u>Symbolic Operands</u> - Alternative to space system factors corresponding on a one-to-one basis to the factors (b) and (c) above. In depicting the symbolic operands' elements, the following designation will be followed:

1an. Design engineering of the given substitute block

2an. Test and evaluation

3an. Production engineering

4an. Prototype Production

5an. Delivery to pilot plant site

Table A1-1. Examples of Characteristics of "National Objectives" Pertinent to Long-Range Planning of Space Technology Program

	Activities & Their Character Previously Depicted as	Neo-Populism	Neo-Mercantilism	Alert-Preparedness
1	Centralized high technology activities	Rejected in favor of provincial project	Encouraged and supported	Mobilized and military defensive features deployed
2	Directives to managerial industrial groups	Trend to management by referendum	Representative-management standards further developed	Enlargement of Military-Industrial sectors
3	Directives to military establishment	Emphasis on defensive techniques and strategies	Emphasis on utilization of coordinated military-diplomatic actions	Forceful stance of rational American threat against encroachment on U.S. interests
4	Character of popular market-place demand and constituency attitudes	Long range benefits discouraged in favor of immediate utility projects	Provided that national economic balance is preserved, long range ventures will be supported	Necessary patriotic-effort-enterprises encouraged
5	Criteria for financing of large scale projects	Popular subscription to well advertised ventures. Pocket-book of subscribers is to be dominant factor.	Proven reliability of management promising economic benefits	Feasibility and timeliness of end result, given allocated resources
6	Comparison criteria between alternatives in (5) above	Alternatives promising decentralized uses and local control would be preferred	Better economic benefits even if longer term developments are the alternatives	Mission fulfillment assurance
7	Effect of commonality of equipments for civilian-military uses on (5) and (6) above	Strict accounting in allocations for military versus civilian uses	If commonality is prominent, allocation of expenses to military uses encouraged for facilitation of projects possessing commonality	Pre-eminent importance of projects with dual (military-civilian) usefulness is to be widely recognized

Note: Alternate sets of "National Objectives" in the columns are exclusively for illustration of the planning approach presented herein. None of them are to be regarded as a forecast.

6an. Assembly of the substitute block prototype on pilot plant site

7an. Test and evaluation of the substitute block prototype on pilot plant site

8an. Modification and refinement of the substitute block prototype

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1aS. Fabrication of operating system

2aS. Test and evaluation

3aS. Delivery to installation sites

4aS. Assembly on installation sites

5aS. Break-in and adjustments

6aS. Maintenance and resupply to T_{MaS} years period

e. Resultant (Measure of Effectiveness) - Difference between (c) - (d) above, with (b) in view. [An example of the quantitative unit to be used in (e) is the mean annual output of one member of the U.S. work force operating with the mean assets available to him.]

A1.4. EVALUATION ALGORITHM

The term "Algorithm" in the context of this section depicts an operational procedure comprising an ordered sequence of steps. Some, or all, of the steps may be iterated. The dominant operational characteristics of the factors under evaluation must be meaningfully abstracted for comparison. In the present subsection we shall endeavor to abstract these dominant characteristics in the form of quantitative entities so that they may be directly comparable with each other.

Because in the present study we are concerned with long-range, large-scale projects of strategic importance for economic and/or military activities of the United States, the abstracted quantities will be referred to as units of the U.S. work force on a nationwide basis, with unweighted mean values of assets and activities to be allocated thereof. This procedure is desirable because industrial districts in the United States, while they

may be geographically spaced without uniformity in many cases, are integrated and interrelated functionally.

Therefore, taking sufficiently large industrial regions containing, say, several million people each, the differences between them would be within statistically significant limits.

For example, while in 1970 the nationwide work force constituted 42.4 percent of the total population (87 million people out of a total of 205 million), we might have, with great statistical confidence, estimated for that year in an industrial district of Southern California, containing a total of 10,000,000 people, some 4,000,000 to be in the work force having urban facilities, industrial plant investment, public utilities, housing investments, etc., on the average equal to a comparable midwestern industrial district containing a total of 10,000,000 people.

Selection and/or identification of such districts on the basis of either the greater differentiation or, to the contrary, aiming at a more precise similarity therebetween, while probably accomplished without great difficulty, is not relevant to the purposes of the present study in its strategic aspects. Such a selection may be undertaken much later, when local circumstances of immediate regional significance would come under a closer planning scrutiny.

Following the organization of the planning procedure offered above and referring to Table A2-2 "Symbols in Alphabetical Order" presented in Section A2, we obtain the expressions for symbolic operators as shown in Figures A1-1, A1-2, and A1-3, and symbolic operands as shown in Figures A1-4, A1-5, and A1-6. Expressions for the resultants ordinarily would be expected to vary from case to case, so only an example suitable for one of the types is presented in Figure A1-7.

Different types would originate in those cases where close one-to-one functional correspondence is not possible to synthesize for the alternative elements to those of space initiatives. Also, purely military applications may entail different operands. In the present phase of the study these cases are outside of the authorized effort.

$$A_{or1} = \sum_{A_{Sb}=1}^{A_{Sb}} 1_{A_{Sb}} \left\{ \sum_{n=1}^{n=8} 1_n \left\{ \left[\frac{1}{T_{n\,1\text{-}8}} \sum_{d_1}^{\left(d_1 + T_{n\,1\text{-}8} - 1\right)} \frac{1}{M_{yd_n}} \right] \left[\frac{1}{T_{n\,1\text{-}8}} \sum_{d_1}^{\left(d_1 + T_{n\,1\text{-}8} - 1\right)} C_{nd_n} \left[F_{ca(c)n} \, \delta_c^J + F_{ca(m)n} \, \delta_c^J + \left(F_{ca(c)n} + F_{ca(m)n}\right) \delta_{cm}^J \right]_J \right] \right\}_n \right\}_{A_{Sb}}$$

NOTE:

1. (α) under "Balance Between Major Powers;" $j = c$
2. (β) under "Instability Between Major Powers;" } $j = cm$
3. (γ) under "Confrontation with Hostile Axis;" }

$$\delta_i^j = \begin{cases} 1 & \text{when } i = j \\ 0 & \text{when } i \neq j \end{cases}$$

$j = c$ under "Trends Towards Isolationism" } All space projects are financed by civilian budget in 1. to 8 items

$j = cm$ under 1 (α) + neo-mercantilism } Space budget is taken from DoD for $F_{ca(m)n}$ from civilian for $F_{ca(c)n}$

$j = cm$ under 1 (β) + neo-New Frontier }

$j = cm$ under 1 (γ) } Entire sum $F_{ca(m)n} + F_{ca(c)n}$ is taken from DoD

Figure A1-1

$$A_{or2} = N \sum_{A_{Sb}=1}^{A_{Sb}} 1_{A_{Sb}} \left\{ \sum_{nS=1S}^{nS=5S} 1_{nS} \left\{ \left[\left[\frac{1}{T_{nS}}_{1S-5S} \sum_{d_{1S}}^{\left(d_{1S}+T_{nS}-1\right)_{1S-5S}} \frac{1}{M_{yd_{nS}}} \right] \right] \left[\left[\frac{1}{T_{nS}}_{1S-5S} \sum_{d_{1S}}^{\left(d_{1S}+T_{nS}-1\right)_{1S-5S}} C_{nSd_{nS}} \left[F_{ca(c)nS}\ \delta_c^j + F_{ca(m)nS}\ \delta_c^j + \left(F_{ca(c)nS}+F_{ca(m)nS}\right) \delta_{cm}^j \right]_j \right] \right] \right\}_{nS} \right\}_{A_{Sb}}$$

Note: Schedule for "j" is the same as in the expression given in Figure A1-1.

Figure A1-2

$$A_{or3} = \left[\left[\frac{1}{T_{MS}} \sum_{d_{1MS}}^{\left(d_{1MS}+T_{MS}-1\right)} \left(A_{or1}+A_{or2}\right) F_{MA_{Sb}} \right] \right] + \left[\left[\frac{1}{T_{MS}} \sum_{d_{1MS}}^{\left(d_{1MS}+T_{MS}-1\right)} \frac{1}{M_{yd_{nMS}}} \right] \right] \left[\left[\frac{(N+1)}{T_{MS}} \sum_{d_{1MS}}^{\left(d_{1MS}+T_{MS}-1\right)} C_{MSd_{nMS}} \cdot \left[F_{ca(c)\,MS}\ \delta_c^j + F_{ca(m)MS}\ \delta_c^j + \left(F_{ca(c)MS}+F_{ca(m)MS}\right) \delta_{cm}^j \right]_j \right] \right]$$

Note: Schedule for "j" is the same as in the expression given in Figure A1-1.

Figure A1-3

$$G_{on1} = \sum_{G_{aSb}=1}^{G_{aSb}} 1_{aSb} \left\{ \sum_{\substack{an=1\\1-8}}^{an=8an} 1_{an} \left\{ \left[\left[\frac{1}{T_{an}}_{1-8} \sum_{d_{1an\ 1-8}}^{\left(d_{1an}+T_{an}-1\right)_{1-8}} \frac{1}{M_{yd_{nan}}} \right] \right] \left[\left[\frac{1}{T_{an}}_{1-8} \sum_{d_{1an}}^{\left(d_{1an}+T_{an}-1\right)_{1-8}} C_{nd_{nan}} \left[F_{ca(c)an}\ \delta_c^j + F_{ca(m)an}\ \delta_c^j + \left(F_{ca(c)an}+F_{ca(m)an}\right) \delta_{cm}^j \right]_j \right] \right] \right\}_{an} \right\}_{G_{aSb}}$$

Note: Schedule for "j" is the same as in the expression given in Figure A1-1.

Figure A1-4

$$G_{on2} = N \sum_{G_{aSb}=1}^{G_{aSb}} 1_{aSb} \left\{ \left\{ \sum_{aS=1aS}^{aS=5aS} 1_{aS} \left\{ \left[\left[\frac{1}{T_{aS \atop 1aS-5aS}} \sum_{d_{1aS}}^{\left(d_{1aS}+T_{aS}-1\right)_{1aS-5aS}} \frac{1}{M_{yd_{naS}}} \right] \right] \left[\left[\frac{1}{T_{aS \atop 1aS-5aS}} \sum_{d_{1aS}}^{\left(d_{1aS}+T_{aS}-1\right)_{1aS-5aS}} C_{aSd_{naS}} \left[F_{ca(c)aS}\,\delta_c^j + F_{ca(m)aS}\,\delta_c^j + \left(F_{ca(c)aS} + F_{ca(m)aS}\right)\delta_{cm}^j \right]_j \right] \right] \right\}_{aS} \right\} \right\}_{G_{aSb}}$$

Note: Schedule for "j" is the same as in the expression given in Figure A1-1.

Figure A1-5

$$G_{on3} = \left[\left[\frac{1}{T_{MaS}} \sum_{d_{1MaS}}^{\left(d_{1MaS}+T_{MaS}-1\right)} \left(G_{on1} + G_{on2}\right) F_{MaS} \right] \right] + \left[\left[\frac{1}{T_{MaS}} \sum_{d_{1MaS}}^{\left(d_{1MaS}+T_{MaS}-1\right)} \frac{1}{M_{yd_{nMaS}}} \right] \right] \left[\left[\frac{(N+1)}{T_{MaS}} \sum_{d_{1MaS}}^{\left(d_{1MaS}+T_{MaS}-1\right)} C_{MaSd_{nMaS}} \left[F_{ca(c)MaS}\,\delta_c^j + F_{ca(m)MaS}\,\delta_c^j + \left(F_{ca(c)MaS} + F_{ca(m)MaS}\right)\delta_{cm}^j \right]_j \right] \right]$$

Note: Schedule for "j" is the same as in the expression given in Figure A1-1.

Figure A1-6

$$R_{ASGaS} = -\left(A_{or1} + A_{or2} + A_{or3}\right) + \left(G_{on1} + G_{on2} + G_{on3}\right)$$

Figure A1-7

Attention should be given to considering the composition of the operators (A_{or1}) and (A_{or2}) as presented in Figures A1-1 and A1-2. It is seen that the effort for engineering and prototype deployment of a given quantity (A_{Sb}) of the Aerospace "Technology Building Blocks" may be allocated between civilian and military efforts in accordance with the algorithmic instruction index (j) as written in the "Note" in Figure A1-1. That instruction applies to both operators with respect to that index. At the same time it must be kept in mind that two pairs of quantities ($F_{ca(c)n}$), ($F_{ca(m)n}$), and ($F_{ca(c)nS}$), ($F_{ca(m)nS}$), while their occurrence in this algorithm is controlled by assignment of the required (j), ordinarily may or may not be congruent as to their magnitudes, except, of course, that the sum of both members in each pair must be unity.

For the present, the above-mentioned magnitudes are left to a command decision, so that the quantity of operating systems (or their time sharing) dedicated to civilian and/or military uses is independent from the allocations of effort in engineering and prototype deployment between the above-mentioned purposes. An analytic aid for facilitating such a command decision can readily be devised later on, if so desired. The same considerations apply to the corresponding factors in the operands, taking into account, of course, that the fractions of costs allocated to military and civilian efforts for any given alternative element (an) of the project would be determined in a different manner from those in the operators.

The expressions for operators and operands, in view of the definition of symbols presented in Section A2 are self-explanatory.* The only subject requiring further discussion concerns the use of unweighted averages over the corresponding time periods (T_n, T_{nS}, T_{MS}, T_{MaS}, etc.). This treatment in the future may be subject to refinement and should be considered

*Uniformity of structure of each corresponding operator-operand pair is deliberately invoked for analytic convenience.

to be a fiist approximation* towards extrapolation of the factors under such averaging, having the single virtue -- absence of conflict with the present econometric techniques -- while otherwise requiring much more extensive consideration for more accurate planning procedures.

It may be noted at the same time that the extrapolated values for $(1/M_{yd_n})$ and (C_{nd_n}), as well as those corresponding to (C_{nd_n}) symbols in other operators and operands such as $(C_{nSd_{nS}})$, $(C_{MSd_{nMS}})$, etc., should not be combined in any extrapolation technique. They, more often than not, are subject to different time-related influences from those applicable to $(1/M_{yd_n})$, $(1/M_{yd_{nS}})$, $(1/M_{yd_{nMS}})$, etc., respectively.

A1.5 SURVIVABILITY OF ALTERNATE SYSTEMS

The algorithms offered as suitable procedures for evaluation of space initiatives demonstrate a very important feature. The feature appertains to the degree of strategic survivability possessed by large-scale installations either space deployed or sea and/or ground-based serving equivalent functions, either of military or economic significance. This is more prominently displayed in the above algorithms due to the satisfactorily obtainable uniformity of the mathematical structure in the operators and operands representing the national effort required by the elements of the space deployed and alternate installations. These are placed in one-to-one correspondence in accordance with our organization of operations research for their comparison, the organization having been devised for that purpose.

For the large-scale installations, it is immediately clear that when an element (A_{Sb}) of a space installation is in one-to-one correspondence with alternate element (G_{aSb}) of its ground-based alternative, then each embraces a strictly delineated set of hardware on an end-result functional basis.

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*We compute here for the unit of a space project effort one man-year output averaged over the period for which (or its part) the unit is planned. Note that this differs from man-year output obtainable during that period. The latter would tend to smooth out the effect of any sudden change foreseeable during that period. That would conflict with our task of long-range planning, in which military action may occur in a given district. Similar factors reflect on units of cost of the elements of the projects under review.

For example, if a power station deployed in space is evaluated by comparison to its equal ground-based counterpart, then the latter may or may not have a security fence with, say, closed circuit supervision, this element being designated to be (G_{aSb}) = No. 24.* This building block would prevent an individual's intrusion but would not prevent, say, commando-type action. The corresponding element (A_{Sb}) = No. 24 of the space deployed power station must then be devised to perform an equal function to the above-mentioned (G_{aSb}) = No. 24.

Conversely, if the strategic requirements are that the given large-scale power station has to be protected against ICBMs, the equal point defenses (G_{aSb}) = No. X and (A_{Sb}) = No. X are to be installed in either case, because both are pretargetable with equal ease. Thus, either a "meta system" [(A_{Sb}) = No. X] for protection of a space deployed power station against missile attack is to be provided to be equal to that of (G_{aSb}) = No. X, or both alternatives are to be left on the lists of strategic probability casualties.

It may be noted that some space initiatives, properly preplanned and developed in a timely manner, promise better point defense capabilities than any known ground-based point defense system.

Thus, for the large-scale systems from the preceding considerations, it is seen that against the strategic hazards these systems, in the age of intercontinental artillery, are equally pretargetable, or otherwise vulnerable, whether they are in orbit or on the ground, and equal defensive meta-systems have to be employed for their protection.

In conclusion, it should be pointed out that the algorithm described here, at the present level of effort expended for its development, constitutes only a "first cut" example of an approach to the quantitative aspects of operations research pertaining to the planning process of the magnitude outlined in this study. In its present stage of development the algorithm

*Both G_{aSb} and A_{Sb} bear identical numeration in operating the algorithm, thus, the No. 24 is purely illustrative.

should be regarded to be a subordinate, albeit useful, evaluation tool for that planning process.

Ordinarily, the present version of the algorithm should be repeatedly applied to and tested on several synthetically composed "functional initiative groupings." In such a task, various parts of the functional initiative groupings would be either modified, enlarged, or found to be adequate with the help of the algorithm as a quantitative tool. Conversely, the new aspects and characteristics of the groupings capable of generalization and useful abstraction would be discovered, optimized, and incorporated into additional algorithms. The latter would influence decisions in further synthesis of such groupings.

While an effort of this type, economically conducted, is recommended and necessary in the next stage of study, it is outside the existing funding and scope of this study. It may be seen, however, that even the present modest effort, through systematic counterpositioning of several correlative factors for the future work, lends sufficient structure to the categories of program plans and initiatives whose broad features have been discussed in the main body of the text.

A2. SYMBOLS AND DEFINITIONS USED IN THE ALGORITHM

The symbols represent acronyms of the definitions in which the first letter is taken as the capitalized letter of the symbol and subsequent letters are placed as subscripts. For example:

T_{nS} = Time period during which (or during its part) the operational steps (1S) through (nS) are planned to be performed. The operational steps are described in Subsection A1.3.

Exceptions to this rule are the indexed "ones" controlling the length of summation series such as (1_{ASb}), (1_n), etc. The acronyms here are only in the subscripts. The letters comprising the symbols-acronyms are underlined in their definitions. The symbols are presented, in Table A2-1, in order of their occurrence in the formulas, but without repetition. Table A2-2 presents the symbols alphabetically.

Table A2-1. Symbols in Order of Their Occurrence

SYMBOL NO.	SYMBOL	DEFINITION	UNIT	REMARKS
1	A_{or1}	Operator delineating the national effort for engineering and deployment of a prototype aerospace system composed of (A_{Sb}) subsystems or hardware assemblies ("Aerospace Operator #1). Note: (A_{or1}) embraces a quantity of (A_{Sb}) blocks composing one prototype subject to the evaluation.	Averaged man year of one member of U.S. work force backed up by averaged productive urban and agrarian resources of U.S.A.	Each assembly goes through (n) operations which may be divided between military and/or civilian efforts in accordance with binary controls in the square brackets indexed by (j), as shown in the formulas.
2	A_{Sb}	Aerospace system block. It is a hardware assembly, or a subsystem, for accomplishing a given function.	Abstract numeral depicting number of the block in the complete installation.	
3	n	A numeral (1, 2, ...8) designating the operational step (1) through (8) described in A1.3.	Abstract numeral	
4	T_n	Time period during which (or its part), (n) operations described in A1.3, 1 to 8, are planned to be performed.	Calendar year	
5	d_1	Date year from which the period (T_n) begins.	A.D. year at start of pre-planned effort for (A_{or1})	

SYMBOL NO.	SYMBOL	DEFINITION	UNIT	REMARKS
6	M_{yd_n}	Average man-year output during (n)-th calendar date year (d_n) included into the period (T_n).	Ratio of U.S. national product in the date year d_n to the number of persons in the work force in that year.	
7	C_{nd_n}	Cost of an operation (n), in dollars of purchasing power projected into the date year (d_n). Note: Operation (n) is within each one assembly (A_{Sb}).	Dollar	Aerospace equipment price indexes are not necessarily in step with average man year output for the given year. Refer to: "Aerospace Price Indexes" by H.G. Campbell, 1970. Publication R-568-PR Rand Corp. Santa Monica, CA
8	$F_{ca(c)n}$	Fraction of cost allocated to civilian effort for the operation (n) within the assembly (A_{Sb}).	Abstract numeral	
9	$F_{ca(m)n}$	Fraction of cost allocated to military effort for the operation (n) within the given one assembly (A_{Sb}).	Abstract numeral	The sum: $\left[F_{ca(c)n} + F_{ca(m)n}\right]$ must be equal to unity.

SYMBOL NO.	SYMBOL	DEFINITION	UNIT	REMARKS
10	$\underset{i}{\overset{j}{\delta}}$ $i = \begin{cases}\text{either "c"}\\ \text{or "cm"}\end{cases}$	Kronecker delta. To be used as a binary control for composition of computer programs using these formulas. Index (c) stands for "civilian significance". Index (cm) denotes elements having both, civilian and military applications.	Abstract numeral (Zero or unity)	Note that the algorithm as offered here resolves into plurality of polynomials whose elements are automatically complemented by means of this notation.
11 12 13	α, β, γ	Three major subdivisions of the possible "Sets of U.S. National Objectives" tabulated in Figure A1-1.	Notation tags. Not numerical values.	
14	A_{or2}	Operator delineating the National effort for fabrication and deployment in space of (N) systems each having (A_{Sb}) subsystems or hardware assemblies. (Aerospace Operator #2) Note: The same collection of (A_{Sb})'s is considered in each one of (N) systems as in (A_{or1}).	Averaged man year of one member of U.S. work force backed up by averaged resources of U.S.A.	Each assembly goes through (nS) operations as described in A1.3.
15	N	Number of deployed systems, in addition to prototype, each embracing full collection of subsystems (that is hardware assemblies) of which every assembly is a component of a system represented by initially engineered prototype or pilot installation.	Abstract numeral	(N) = zero when a prototype, or a pilot installation is the only one to be deployed and/or operated as a working system.
16	nS	A numeral (1S, 2S, ... 5S) designating the operational steps (1S) through (5S) described in A1.3.	Abstract numeral	

SYMBOL NO.	SYMBOL	DEFINITION	UNIT	REMARKS
17	T_{nS}	Time period during which (or its part) (1S)through (nS) operational steps described in A1.3 are planned to be performed.	Calendar year	
18	d_{1S}	Date, year, from which the period (T_{nS}) starts.	A.D. year of start of pre-planned effort for (A_{or2})	
19	$M_{yd_{nS}}$	Average man-year output during (nS)-th calendar date year included into the period (T_{nS}).	Ratio of U.S. GNP in the year (d_{nS}) to the number of persons in the work force in that year.	
20	$C_{nSd_{nS}}$	Cost of the operation (nS) in dollars of purchasing power projected into the date year (d_{nS}). Note: Operation (nS) is within each one assembly (A_{Sb}).	Dollar	See remarks to the definition of (C_{nd_n})
21	$F_{ca(c)nS}$	Fraction of cost allocated to civilian effort in the operation (nS) within the assembly (A_{Sb}).	Abstract numeral	sum of these two fractions is unity
22	$F_{ca(m)nS}$	Same as ($F_{ca(c)nS}$) but the fraction is allocated to military effort.	Abstract numeral	

SYMBOL NO.	SYMBOL	DEFINITION	UNIT	REMARKS
23	A_{or3}	Operator delineating the National effort for maintenance and resupply of (A_{or2}) systems deployed under prototype delineated by (A_{or1}) for the period of (T_{MS}) years. The operator includes capital return and charges translated into units of U.S. work-force as indicated. (Aerospace Operator #3)	Averaged man year of one member of U.S. work force backed-up by averaged resources of U.S.A.	
24	T_{MS}	Time period for maintenance and resupply equal to preplanned ammortization period for the deployed systems.	Calendar year	
25	d_{1MS}	Date year from which the period (T_{MS}) starts.	A.D. year	
26	$F_{MA_{Sb}}$	Fraction representing preplanned capital return and charges for the year (d_{nMS}) included into the period (T_{MS}) for maintenance of aerospace system blocks deployed.	Abstract numeral less than unity.	
27	$M_{yd_{nMS}}$	Average man-year output during (n)-th calendar date year included into the period (T_{MS}) dedicated to maintenance of systems as deployed.	Ratio of U.S. National product in the date year (d_{nMS}) to the number of persons in the work force in that year.	
28	$C_{MSd_{nMS}}$	Cost of the maintenance and resupply, (excluding capital return and charges for deployed systems) for each one space system in dollars of purchasing power projected into the (n)-th calendar date year (d_{nMS}) included into the period (T_{MS}).	Dollar	Refurbishing, operation, and capital return and charges on space shuttles and/or tugs are a part of ($C_{MSd_{nMS}}$)

SYMBOL NO.	SYMBOL	DEFINITION	UNIT	REMARKS
29	$F_{ca(c)MS}$	Fraction of cost allocated to civilian effort in the maintenance of space deployed systems included in (A_{or1}) and (A_{or2}).	Abstract numeral	Sum of these two fractions is unity.
30	$F_{ca(m)MS}$	Same as ($F_{ca(c)MS}$) but the fraction is allocated to military effort.		
31	G_{on1}	Operand delineating the National effort for engineering and erection on pilot plant site (including tests, refinements and adjustments) of a prototype alternate to aerospace system performing identical function. (G_{on1}) is composed of (G_{aSb}) subsystems, or assemblies. ("Ground System Operand #1") Note: (G_{on1}) embraces a quantity of (G_{aSb}) blocks (or hardware assemblies) composing one prototype performing identical function to (A_{or1}).	Same as for (A_{or1})	Note the remarks to the definition of A_{or1}.
32	G_{aSb}	Ground alternative system block. It is a hardware assembly or a subsystem for accomplishing a given function.	Abstract numeral depicting number of the block in the complete installation.	
33	an	A numeral (1an, 2an.... ...8an) designating an operational step in engineering and installing on pilot plant site an alternate prototype. The steps are described in Subsection A1.3(d).	Abstract numeral	

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SYMBOL NO.	SYMBOL	DEFINITION	UNIT	REMARKS
34	T_{an}	Time period during which (or its part) (an) operations decribed in ¶A1.3(d) are planned to be performed.	Calendar years	
35	d_{1an}	Date year from which the period (T_{an}) begins.	A.D. year of start of preplanned effort for G_{on1}	
36	$M_{yd_{nan}}$	Average man-year output during (n)-th calendar date year included into the period (T_{an}) for the alternate operations (an).	Ratio of GNP in the year (d_{nan}) to the number of persons in the work force for that year.	
37	$C_{nd_{nan}}$	Cost of the operation (nan) in dollars of purchasing power projected into the date year (d_{nan}). Note: Operation (nan) is within each one assembly (G_{aSb}). The (nan) steps are described in A1.3(d).	Dollar	See remarks to the definition of (C_{nd_n}).
38	$F_{ca(c)an}$	Fraction of cost allocated to civilian effort for the (nan)-th operation within an assembly (G_{aSb}).	Abstract numeral	Sum of these two fractions is unity.
39	$F_{ca(m)an}$	Fraction of cost allocated to military effort for the (nan)-th operation within the assembly (G_{aSb}).	Abstract numeral	

SYMBOL NO.	SYMBOL	DEFINITION	UNIT	REMARKS
40	G_{on2}	Operand delineating the National effort for fabrication and deployment on operation sites of (N) systems each having (G_{aSb}) subsystems hardware assemblies. (Ground System Operand #2) Note: The same collection of (G_{aSb}) subsystems, or hardware assemblies is considered in each one of (N) systems as (G_{aSb}) in the expression (G_{on1}) for the prototype.	Same as in (A_{or2})	
41	aS	A numeral (1aS, 2aS....5aS) designating an operational step in fabrication and deployment on operational site of an operating system alternate to that described by (A_{or2}). The steps are described in A1.3(d).	Abstract numeral	
42	T_{aS}	Time period during which (or any of its part) the (aS) operations described in A1.3(d) are planned to be performed.	Calendar year	
43	d_{1aS}	Date year from which the period (T_{aS}) begins.	A.D. year of start of preplanned effort	
44	$M_{yd_{naS}}$	Average one man-year output during (n)-th calendar date year included into time-period (T_{aS}).	Gross National product in the year (d_{naS}) divided by the number of persons in the work force for that year.	

SYMBOL NO.	SYMBOL	DEFINITION	UNIT	REMARKS
45	$C_{aSd_{naS}}$	Cost of the operation (aS) in dollars of purchasing power projected into the date year (d_{nas}). Note: Operation (naS) is within each one assembly (G_{aSb}).	Dollar	See remarks to the definition of (C_{nd_n}).
46	$F_{ca(c)aS}$	Fraction of cost allocated to civilian effort for the (naS)-th operation within an assembly (G_{aSb}).	Abstract numeral	Sum of these two fractions is unity.
47	$F_{ca(m)aS}$	Same as ($F_{ca(c)aS}$) but the fraction is allocated to military effort.	Abstract numeral	
48	G_{on3}	Operand delineating the National effort for maintenance and resupply of alternate systems (G_{on2}) installed under prototype-pilot-installation delineated by G_{on1}) for the period of (T_{MaS}) years. The operand includes capital return and charges translated into units of U.S. work-force as indicated. (Ground System Operand #3)	Averaged man-year of one member of U.S. work-force backed up by averaged resources of U.S.A.	
49	T_{MaS}	Time period for maintenance and resupply equal to preplanned amortization period for alternate systems.	Calendar year	
50	d_{1MaS}	Date year from which the period (T_{MaS}) starts.	A.D. year	
51	F_{MaS}	Fraction representing preplanned capital return and charges for the year (d_{nMaS}) included into the period (T_{MaS}).	Abstract numeral	

SYMBOL NO.	SYMBOL	DEFINITION	UNIT	REMARKS
52	$M_{yd_{nMaS}}$	Average man-year output during (n)-th calendar date year (d_{nMaS}) included into the period (T_{MaS}).	Ratio of GNP to work force during (d_{nMaS}) year.	
53	$C_{MaSd_{nMaS}}$	Cost of the maintenance and resupply (excluding capital return and charges for the alternate deployed installations) for each one alternate system in dollars of purchasing power projected into the (n)-th date year (d_{nMaS}) included into the time period (T_{MaS}).	Dollar	
54	$F_{ca(c)MaS}$	Fraction of cost allocated to civilian effort in the maintenance of alternate systems included into (G_{on1}) and (G_{on2})	Abstract numeral	Sum of these two fractions is unity.
55	$F_{ca(m)MaS}$	Same as ($F_{ca(c)MaS}$) but the fraction is allocated to military effort.	Abstract numeral	
56	R_{ASGaS}	Resultant of evaluation of aerospace system versus ground alternative - system.	Averaged man year of one member of U.S. work force backed up by averaged resources of U.S.A.	

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Table A2-2. Symbols in Alphabetical Order

ALPHABETICAL OCCURRENCE NUMBER IN THE PRESENT TABLE	SYMBOL	NUMBER OF THE SYMBOL IN THE PRECEDING TABLE	REMARKS
1	an	33	All definitions are in the preceding table.
2	A_{or1}	1	
3	A_{or2}	14	
4	A_{or3}	23	
5	aS	41	
6	A_{Sb}	2	
7	$C_{aSd_{naS}}$	45	
8	$C_{MaSd_{nMaS}}$	53	
9	$C_{MSd_{nMS}}$	28	
10	C_{nd_n}	7	
11	$C_{nd_{nan}}$	37	
12	$C_{nSd_{nS}}$	20	
13	d_1	5	
14	d_{1an}	35	
15	d_{1aS}	43	
16	d_{1MaS}	50	

ALPHABETICAL OCCURRENCE NUMBER IN THE PRESENT TABLE	SYMBOL	NUMBER OF THE SYMBOL IN THE PRECEDING TABLE	REMARKS
17	d_{1MS}	25	
18	d_{1S}	18	
19	$F_{ca(c)an}$	38	
20	$F_{ca(m)an}$	39	
21	$F_{ca(c)aS}$	46	
22	$F_{ca(m)aS}$	47	
23	$F_{ca(c)MS}$	29	
24	$F_{ca(m)MS}$	30	
25	$F_{ca(c)MaS}$	54	
26	$F_{ca(m)MaS}$	55	
27	$F_{ca(c)n}$	8	
28	$F_{ca(m)n}$	9	
29	$F_{ca(c)nS}$	21	
30	$F_{ca(m)nS}$	22	
31	F_{MaS}	51	
32	$F_{MA_{Sb}}$	26	

ALPHABETICAL OCCURRENCE NUMBER IN THE PRESENT TABLE	SYMBOL	NUMBER OF THE SYMBOL IN THE PRECEDING TABLE	REMARKS
33	G_{aSb}	32	
34	G_{on1}	31	
35	G_{on2}	40	
36	G_{on3}	48	
37	M_{yd_n}	6	
38	$M_{yd_{nan}}$	36	
39	$M_{yd_{nMS}}$	27	
40	$M_{yd_{nMaS}}$	52	
41	$M_{yd_{nS}}$	19	
42	$M_{yd_{naS}}$	44	
43	N	15	
44	n	3	
45	nS	16	
46	R_{ASGaS}	56	
47	T_{an}	34	
48	T_{aS}	42	

ALPHABETICAL OCCURRENCE NUMBER IN THE PRESENT TABLE	SYMBOL	NUMBER OF THE SYMBOL IN THE PRECEDING TABLE	REMARKS
49	T_{MS}	24	
50	T_{MaS}	49	
51	T_n	4	
52	T_{nS}	17	
53 54 55	α β γ	11 12 13	
56	δ_{i}^{j}	10	In this symbol designating the Kronecker delta, the subscript (i) is either (c) or (cm) and superscript (j) is likewise either (c) or (cm) as denoted in Figure A1-1.

A3. ANNOTATION ON THE USE OF THE ALGORITHM

A3.1. COMMENTS ON COMPUTATIONAL FEATURES OF THE ALGORITHM OFFERED IN SECTION A1 AND ON THE TRENDS IN AEROSPACE INDUSTRIES

Some comments on broader features concerned with large-scale aerospace programs are now in order, for the illustration of capabilities inherent in the algorithm presented in Section A1.

Comments on the comparisons of trends evaluated previously by similar computation for other industries have been omitted, and some numerical data for the aerospace industry will now be introduced. The work of H. G. Campbell (Rand Corporation Publication #R-568-PR) mentioned under Item 7 in Table A1-1, will be used here for the numerical indexes of aerospace projects. Taking into account all the remarks concerning precision of the figures attained in the above-mentioned H. G. Campbell report*, it may be stated that the precision is more than sufficient for demonstration of one of the trends which will now be investigated.

The trend is in the aerospace industry for the decade** 1959-1969, and the figures desired are the products within the braces $\{nS\}$ of the algorithm for (A_{or2}), with stipulation that (j) = (cm), which brings the sum

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* Note that the work exhibits all the earmarks of meticulous quality of intellectual diligence and may be placed amongst the examples of excellence in the area abounding with many difficulties.

** The decade 1956-1969 is selected because for this period all desired economic factors are available and this period contains many typical "norm" features for the U.S. aerospace industry.

of components within the braces [j] to be, uniformly, unity*. Further, the values for $(C_{nSd_{nS}})$ were set to be average to obtain $1 billion for a three-year period (1958-60), as the beginning of the decade; whereas corresponding price-indexed $(C_{nSd_{nS}})$ are to be averaged for a three-year period (1968-70), as the end of the decade. For values $(M_{yd_{nS}})$ the same calendar years will be averaged for the beginning and end of the decade, with the data from the U.S. Bureau of Labor Statistics (BLS) being utilized**.

The information sought by this computation concerns availability and utilization in the aerospace industry of an averaged group of the U.S. work force for each $1 billion of composite aerospace projects in the 1958-60 period as compared to the same in the 1968-70 period. The unemployment rate, whenever it deviates from the overall norms, will demonstrate itself in the resultant figures, as shall be seen presently. Therefore, the total available U.S. work force as presented by the BLS shall be used for computations of (M_{yd_n}). For multipliers in discounting monetary inflation, the aerospace equipment price indexes shall be taken from Table 12 (page 27) of the Rand Corporation publication by H. G. Campbell.

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*In applying the algorithm to the evaluation of functional initiatives groupings, the expression inside the braces {nS} would come out, of course, as the polynomial of two members in accordance with the fractions:

$$\left[\left(F_{ca(c)nS} + F_{ca(m)nS}\right)\overset{j}{\underset{cm}{\delta}}\right]_{j=cm}$$

In the present computation, however, the distribution between military and civilian budgets is disregarded because we desire to establish here the composite National data.

**BLS data employed here is adjusted and smoothed to eliminate influences in reporting dates and formats thereof. Also the data from Conference Board Corporation was used to supplement the BLS data.

With the above inputs the following data were obtained for the start of the above-mentioned decade:

$$\left[1/3 \sum_{d_{1S}=1958}^{1960} \frac{1}{M_{yd_{nS}}} \right] \left[1/3 \sum_{d_{1S}=1958}^{1960} C_{nSd_{nS}} \right] \cong \begin{matrix} 155,630 \\ \text{Man years} \end{matrix} \qquad (1)$$

While for the end of the decade:

$$\left[1/3 \sum_{d_{1S}=1968}^{1970} \frac{1}{M_{yd_{nS}}} \right] \cdot \left[1/3 \sum_{d_{1S}=1968}^{1970} C_{nSd_{nS}} \right] \cong \begin{matrix} 164,500 \\ \text{Man years} \end{matrix} \qquad (2)$$

Expressions (1) and (2) measure allocation-proportions of personnel relative to the total U.S. work force, which were each to be supported by $1 billion of composite aerospace projects at the beginning and end of the 1959-69 decade. They show an increase of about 5.6 percent in the 1968-70 period as compared to the 1958-60 period <u>for the same work</u>.

While a 5.6 percent increase may be within the precision margin of the Campbell work on price-indexes and BLS data, the above-mentioned expressions nevertheless conclusively establish that, within the aerospace industry, any technological progress during the 1959-69 decade was at least negated. The expenditures of dollars of the 1968-70 issue per each billion dollars of the 1958-60 issue in these composite aerospace projects, show an increase of about 74 percent; whereas the Gross National Product averaged an increase per member of total U.S. work force of only 64 percent in dollars of the issues of corresponding periods (i.e., 1968-70 vs. 1958-60).

Thus, in the 1959-69 decade the expenditures, for the same work in basic national resources in real constant values, show an acceleration* within the aerospace activities which is coupled with an unpredictable influence of the depreciating dollar on the essential strategic imports. These circumstances represent, for the large-scale aerospace projects, a most serious and demanding problem to be addressed as one of the first priority tasks in long-range planning.

The above example illustrates an aspect of utility to the long-range aerospace program planner in the further monitoring of similar data, and indicates additional desirable work which could be accomplished by use of the separate parts of the algorithm presented in Section A1. Note that it is but one aspect, taken at random, to illustrate general available directions thereof.

Numerical examples for the illustration of various particular applications of the algorithm are beyond the scope of the current effort. Additionally, the amount of computation required for quantitative evaluation of functional initiative groupings transcends manual computational capacity. Therefore, the algorithm should be coded into a computer program, for which it is especially suitable.

The above considerations should be kept in mind in perusal of Subsection A3.2, which presents some additional annotations pertaining to the use of this quantitative approach in the evaluation and refinement of the composition of functional groupings of initiatives.

*Absence of influence of technological progress within the decade on the productivity in aerospace composite projects is indicative of sociological nonutilization of investments into facilities for such progress, hence the "stand-still" on productivity in composite large-scale projects means acceleration of real expenditures.

A3.2 COMMENTS ON COMPOSITION OF SPACE SYSTEM FUNCTIONAL INITIATIVE GROUPINGS

Functional Initiative Groupings in the National Space Program Long-Range Planning, as has been pointed out in the main text, and in Section A1 of this appendix, are fundamentally dependent on the National Strategic Planning. The latter should determine the set of the most probable National Objectives for the mid-range of the present study, approximately sometime about 1990.

It may be noted by way of reference, that the Marshall Plan (which was essentially ready for implementation in the 1948-49 period) did describe for its mid-range period (1960) the U.S. National environment for which many large-scale technological operations in the United States were initiated and projected in the 1948-50 period. These ventures have been executed successfully and with complete and justifiable reliance on the Marshall Plan during the 1950-60 decade*.

Without a similar overall strategic plan the functional groupings of initiatives as offered in this report demonstrate, in an appropriately structured format, the influence of several sets of possibilities in the U.S. National environment on such long-range, large-scale programs and their associated initiatives. In the present study, the examples of functional groupings of initiatives or "program plans" are the result of opinions of the authors, and though they may be reasonable, have no official sanction, and cannot be used for input to this algorithm.

The approach to the planning method and criteria, as offered, affords a quantitative procedure for refinement and/or modification of

*There are several previous writings on the factors and doctrines employed in the Marshall Plan which rendered that plan to be a series of self-fulfilling prophesies as long as the plan was appropriately implemented in U.S. policies.

these program plans. Such an approach, however, should be regarded now to be only "a suit cut to the cloth;" i.e., it is determined by the resources allocated for this part of the study and by the fact that the above-mentioned space strategic plan is not at hand now.

More extended operations research effort may be performed so that structuring of the functional initiative groupings would be generated more directly. This should be done after the most probable mid-range set of National Objectives is developed in the strategic plan. The operations research of that type would be a massive effort and is not recommended for an illustrative set (or still worse, for several sets each having an undefined probability of occurrence for said mid-range period).

In view of these considerations, comments and remarks shall be restricted to the methodology, as outlined in the previous sections. Figures A3-1 and A3-2 indicate schematically the structure of the interdependences. The accompanying legends on these sketches make them self-explanatory. Note that in Figure A3-1, for clarity of the drawing, only the "Sets of National Objectives" 2 and 4 are shown with illustrative schematics of some functional initiative groupings. In Section A1, however, in which these groupings are tabulated, each set of National Objectives has several initiative groupings appropriately detailed, to which attention of the reader is hereby directed.

Especial attention should be paid to those functional initiative groupings in which there occur disproportionally many of the negative (R_{ASGaS}) -- that is if there is a dominance of the arrows pointing to the left in Figures A3-1 and A3-2. In some cases, a few initiatives in a given functional grouping may be allowed to have negative resultants (R_{ASGaS}). But every such grouping should be iteratively analyzed.

Upon such an analysis, it may be found that retention of the initiatives with negative (R_{ASGaS}) in the given functional grouping increases the positive resultants of other initiatives in the same group. Then the operational synthesis for the given grouping may be regarded to be one of the near-optimal type.

Arrows pointing to (+) and (-) directions at each initiative depict the values of resultants (R_{ASGaS}) to be computed as per Figure A1-8.

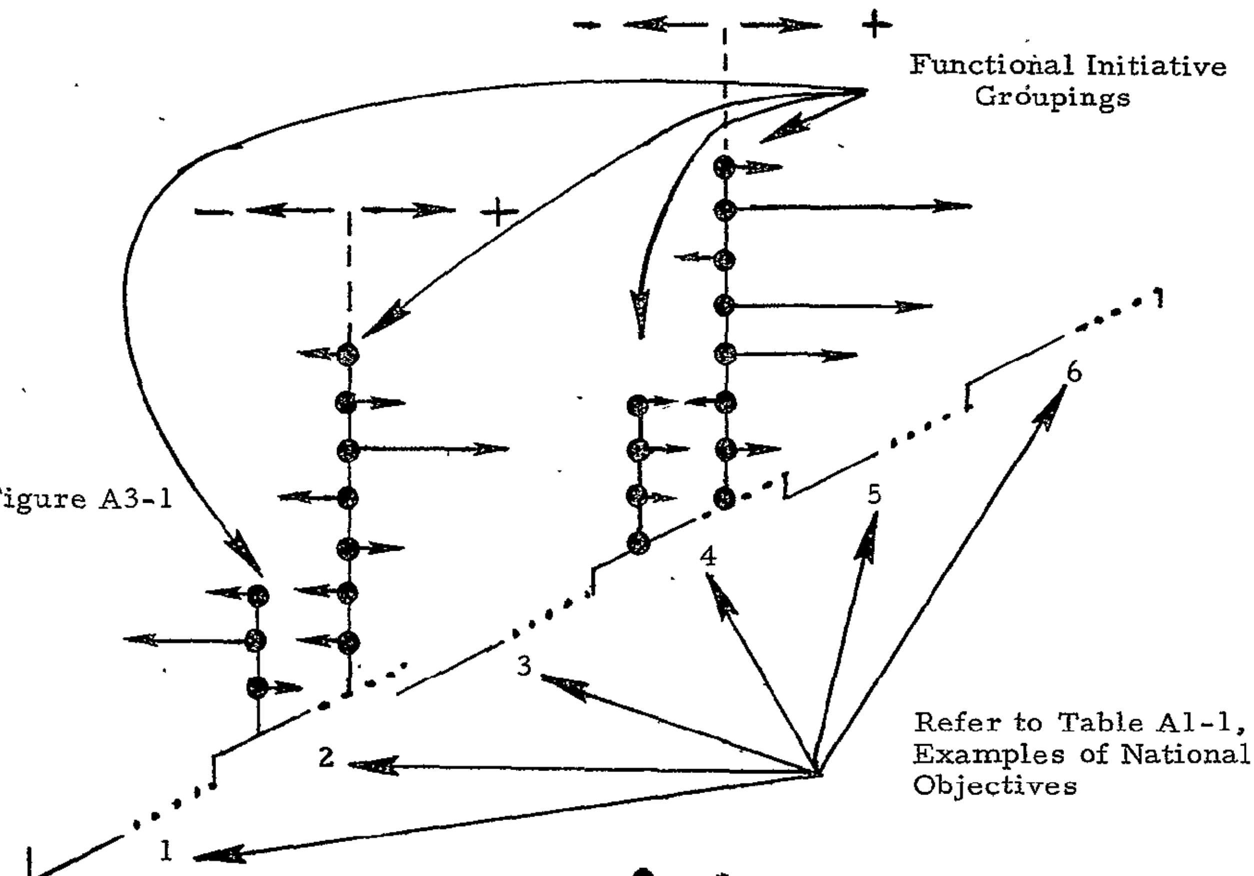

Figure A3-1

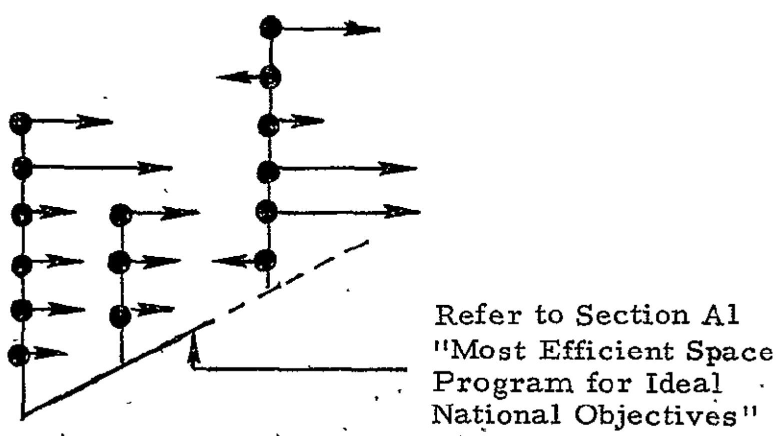

Figure A3-2

In conclusion, it should be pointed out once again, that the presently offered methodology for composition, evaluation, and iterative refinement of Functional Initiative Groupings is a "firct-cut" effort. It comprises, however, a sufficiently optimal synthesis procedure, although appreciable enlargement, improved insights, and great budgetary economies may be achieved by further work, utilizing the notions presented in the sections pertaining to its composition.